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ARTICLES

RECENT STUDIES OF MOSQUITO RESISTANCE TO INSECTICIDES IN CALIFORNIA [1]

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AND

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The warm weather and the frequent irrigations in the San Joaquin Valley of California provide ideal conditions for the production of mosquitoes. In the Valley are large grass pasture areas, many of which contain ladino clover. *Aedes nigromaculis* (Ludl.), which is the most important species, propagates mainly in these situations. Large numbers of this species are also found in low grassy spots in alfalfa fields. Thurman *et al.* (1951) have shown that pasture lands may be irrigated as many as 18 times during a season and that a new generation of *A. nigromaculis* is produced after each irrigation. *A. dorsalis* Meig. is also abundant in grass pastures during the spring months. *Culex tarsalis* Coq. breeds in situations where water accumulates, especially in rice fields, around duck clubs, and in cotton fields after the fall irrigation. *C. quinquefasciatus* Say builds up large populations rapidly in dairy drains and sewer farms in the summer and fall months. Several other less important species are also to be found in the Valley.

DDT mosquito larvicides were first used in the San Joaquin Valley in 1945, and in 1946–47–48 this insecticide was used for nearly all control work. The resistance of mosquitoes to DDT was first reported by Smith (1949) in Kern County, but failures with this larvicide had also been reported in other districts. In a survey of resistance to DDT in *A. nigromaculis* larvae in 1949, Bohart and Murray (1950) found that the average larva from three treated fields in Tulare County was about 10 times as resistant as the average larva from three untreated fields in Kings County.

In 1949, some of the districts began to use toxaphene exclusively, and other districts used toxaphene for some conditions and DDT for others. Benzene hexachloride has been used for special situations since it became available, and lindane has had similar use since 1950. Gamtox, a product containing gamma benzene hexachloride, has also been used in some districts. Toxaphene, benzene hexachloride, and lindane, as well as DDT, failed to give control in certain areas in 1950–51.

In 1951 laboratory tests were made at Bakersfield, Visalia, Fresno, and Merced to determine the degree of resistance that had developed to DDT, toxaphene, lindane, and aldrin in the more important species in these districts. These tests were begun on April 4 and continued until October 20.

Methods and Materials.—Larvae were gathered from breeding places that had been controlled with chlorinated hydro-

[1] A cooperative project between the Bureau of Entomology and Plant Quarantine, the Bureau of Vector Control of the California Department of Public Health, and several mosquito-abatement districts in California. Several Bureau of Vector Control employees, including Grafton Campbell and Malcolm White, assisted with the project, as well as personnel of the San Joaquin Valley mosquito-abatement districts.

carbon insecticides and also from untreated adjacent areas. They were collected with dippers and transported to the laboratories in 1-gallon vacuum jugs. The resistance to the insecticides was based on the parts per million of insecticide necessary to give 50 per cent mortality of the larvae.

The tests were made with early fourth-instar larvae. To 200 cc. of tap water[1] in a glass container sufficient acetone solution of the insecticide was added to give the desired concentration. Twenty larvae were then placed in each container, and two replications were used for each collection. The solutions were maintained at 80° F., and larval mortality was determined after 24 hours.

Each insecticide was tested at four or five different strengths on each collection of larvae. The dosages were adjusted to obtain kills of more than 1 per cent and less than 100 per cent in as many tests as possible. The number of parts per million of each insecticide required to give 50 per cent kill is based on the results of two replications made with from two to eight collections of larvae.

In several counties tests were made in both the spring and fall months to obtain information on seasonal differences in resistance. Larvae were taken from the same general area in both seasons.

From each location where larvae were collected, 1-gallon samples of water were taken and sent to the California Department of Public Health for plankton determinations and analysis of dissolved chemicals.

Discussion of Results.—The results of the tests with *Aedes* larvae are given in table 1.

The resistance to DDT of *A. nigromaculis* larvae from the treated areas was from three to seven times as great as that of larvae from untreated check areas. In all tests except the one made in September in the Tulare District the resistance was from five to seven times greater than that of the larvae from the check area. The low resistance indicated at Tulare is due to the high LD-50 obtained for DDT in the Kings County check area. It is possible that the larvae in this check area were subjected to DDT in some way during the summer, since the LD-50 requirement was over twice as much as for other check areas and for the May test in this area.

In August the *A. nigromaculis* larvae in the Peacock-Canfield area in the Kern District were more than three times as resistant to DDT as the larvae taken in April. This was apparently due, at least in part, to the application of DDT by the syphon method as reported by Geib and Smith (1949). By this method the emulsion is delivered into the irrigation water before it flows onto the fields and kills the larvae as they hatch. The method was used in this district in 1949, but discontinued when larvae became resistant and could not be controlled with 0.25 p.p.m. The 1951 applications were made in June and July to determine whether the larvae were still resistant. In these tests 0.25 p.p.m. was effective for two irrigations but failed in the third. In the next two irrigations 0.35 and 0.5 p.p.m. also failed to give control. Larvae from this district were also about twice as resistant to toxaphene, lindane, and aldrin as were the larvae from the check. Except in two tests with toxaphene, all larvae from treated areas showed less than twice as much resistance to these materials as those from untreated areas.

Larvae taken from an alkali-flat area in the Delta District in September were found to be about three times as resistant to toxaphene as were larvae from the check area. The managers of this and other districts have found that the failure of toxaphene in such areas occurs in the fall months, and coincides with a reduced permeability of the soil and more standing water. Normal permeability is restored by the following spring, and toxaphene is again effective at normal dosages.

Larvae from this alkali-flat area were

[1] The tap water used in the different areas showed no significant variation in percentage of kill.

also tested in the water in which they were breeding and in mosquito-breeding water from a nonalkali area. Toxaphene was equally effective in both types of breeding water, but the mortality was higher than that obtained in tap water. It therefore appears that failure of toxaphene in control operations in this area is due to the resistance of the larvae and not to any effect of the alkaline water on the toxaphene emulsions.

A. dorsalis larvae required slightly larger doses of DDT, lindane, and aldrin for 50 per cent kill than did *A. nigromaculis*. Larvae of *A. dorsalis* from the Hilmar area in the Merced District showed a DDT resistance 12 times that of the larvae from the check area. This result was comparable to one with *A. nigromaculis* larvae obtained from this area in which resistance to DDT was fairly high and no resistance to toxaphene was indicated. Heavy applications of both these materials have failed to give control of larvae in this area.

As shown in table 2, *C. tarsalis* larvae in

TABLE 1.—Dosages required for 50 per cent kill of *Aedes* larvae in San Joaquin Valley as determined in duplicate tests of from two to eight larval collections from each area.

Area [1]	Time of Tests	LD-50 in p.p.m.			
		DDT	Toxaphene	Lindane	Aldrin
		Aedes nigromaculis			
Kern County:					
Peacock-Canfield [2]	April	0.025	0.020	0.005	0.0046
Lane-Trout	April	.077	.05	.0069	.007
Sargent Ranch (check) [2]	April	.0106	.0113	.0042	.004
Peacock-Canfield	August	.0909	.0454	.0154	.010
Canfield	August	.066	.033	.0105	.0079
Sargent Ranch (check)	August	.0120	.0209	.0063	.0045
Tulare and Kings Counties: [3]					
Delta and Tulare Districts	May	.059	.0204	.0063	.0037
Kings County (check)	May	.0114	.0200	.0147	.0031
Delta alkali flat	September	.0952	.0769	.0086	.0061
Tulare District	September	.0571	.0204	.0085	.0056
Kings County (check)	September	.0370	.0238	.0087	.0056
Fresno, Madera, and Kings Counties: [3]					
Consolidated and Fresno Districts	May–June	.0999	.0190	.0058	.0040
Madera District	May–June	.0833	.0175	.0192	.0054
Kings County (check)	May	.0114	.0200	.0147	.0031
Merced and Fresno Counties:					
Near Merced, Merced District	July–Aug.	.0909	.0213	.0067	.0050
Fresno County (check)	July–Aug.	.0149	.0147	.0060	.0038
Hilmar area, Merced District	July–Aug.	.1111	.0190	.0074	.0011
		Aedes dorsalis			
Kern and Kings Counties:					
Sargent Ranch (check)	April	.026	.04	.019	.0071
Greenfield Ranch	April	.090	.043	.028	.0079
Kings County (check)	May	.026	.021	.022	.0046
Merced County:					
Near Merced, Merced District	July–Aug.	.1111	.050	.0263	.020
Hilmar area, Merced District [4]	July–Aug.	.3333	.0454	.0277	.0076

[1] All areas were treated except those indicated as checks.
[2] 22 per cent of larvae were *A. dorsalis*.
[3] Untreated portions of Kings and Fresno Counties were used as checks for Tulare, Fresno, Madera and Merced Counties.
[4] 27 per cent of larvae were *A. vexans*.

TABLE 2.—Dosages required for 50 per cent kill of *Culex* larvae in San Joaquin Valley as determined in duplicate tests of from two to four larval collections from each area.

Area [1]	Time of Tests	LD-50 in p.p.m. DDT	Toxaphene	Lindane	Aldrin	Hepta-chlor
		Culex tarsalis				
Kern County:						
Poso Creek (check)	April	0.0093	0.0143	0.0118	0.0012	.....
Peacock Ranch	April	.077	.0147	.0100	.0023	.....
Poso Creek (check)	August	.0154	.0303	.040	.0031	0.0018
Paloma field and Stockdale Road [2]	August	.0555	.0370	.0312	.0023	.....
Pin Tail Duck Club	August	.0303	.2857	.020	.1250	.....
Ware Duck Club	August	.1539	1.00	.479	.6666	2.4
Fresno and Kings Counties:						
Fresno and Consolidated Dist.	June	.0641	.0175	.0164	.0016	.....
Consolidated Districts	October	.0833	.0217	.0345	.0022	.....
Kings County (check)	October	.0333	.0175	.0213	.0016	.....
		Culex quinquefasciatus				
Merced County:						
Cannery Waste [3]	July	.0555	.0277	1.0 [3]	.0057	.....
Tulare and Kings Counties:						
Dairy drain, McCuen Ranch	September	.0769	.2222	.1389	.0166	.1429 [4]
Dairy drain, #2 ranch	September	.0250	.0779	.0526	.0073	.0714
Visalia sewer farm	September	.0455	.0909	.0526	.0130	.....
Fresno and Madera Counties:						
Firebaugh sewage plant	October	.0777	.0714	.05	.0108	.0117 [4]
Madera sewage plant	October	.0711	.1111	.0713	.0192	.0151 [4]
Consolidated District	October	.0588	.0713	.0370	.0041	.....

[1] All areas were treated except those indicated as checks.
[2] 34 per cent of larvae were *C. quinquefasciatus*.
[3] 45 per cent of larvae were *C. tarsalis*.
[4] One larval collection.

the Kern District were found in April to have a resistance to DDT eight times that found in the check area and no resistance to the other three insecticides. Lower resistance to DDT and none to the other insecticides were found in a few tests in other districts during the summer. This pattern was completely changed when tests were made in August in the duck club area of the Kern District, where applications of aldrin and toxaphene were failing to give control. The larvae from the Ware Duck Club were found to be ten times as resistant to DDT, approximately 33 times as resistant to toxaphene, 11 times as resistant to lindane, and 215 times as resistant to aldrin as larvae in the check areas. These larvae were approximately 1,300 times as resistant to heptachlor as the larvae from Poso Creek. Heptachlor and lindane had not been used for control in this area. A few tests with parathion indicated that larvae from the duck-club area might be slightly more susceptible to this material than the untreated larvae from Poso Creek.

Larvae from the Pin Tail Duck Club, less than half a mile from the Ware Club, were 2, 9, 5, and 40 times as resistant, respectively, to DDT, toxaphene, lindane, and aldrin as larvae from the Poso Creek area. The lower resistance found in the Pin Tail Club area is apparently not due to variations in insecticide applications, for both club areas have been treated with the same insecticides for several years.

Analysis of water samples (table 3) from the Pin Tail Duck Club showed that this area had approximately the same amount of dissolved chemicals as the water from Paloma field about 11 miles away in the Kern District, where *C. tarsalis* showed moderate resistance to DDT only. Water from the Ware Duck Club, where the high resistance in *C. tarsalis* larvae was found, had 49 times as much chloride, 141 times as much sulphate, 6 times as much calcium, 16 times as much magnesium, and 17 times as much sodium as water from the Pin Tail Club. This analysis strongly suggests that these chemicals may be a cause of the high resistance found in the larvae at the Ware Club, and that the lower resistance in the larvae from the Pin Tail Club, which is less than ½ mile distant, may be due to migration of adults from the Ware Club. Further tests will be necessary to determine whether resistance in the area has developed in this way.

Water from the Poso Creek area was also high in sodium, chloride, and sulphate, but no insecticide had been applied here. It is possible that larvae develop high resistance in waters containing large amounts of these chemicals only when repeated applications of insecticides have been made.

Larvicide applications on the duck-club area have been almost entirely by plane. DDT dosages ranged from 0.2 to 1.3 pounds per acre during the period from 1946 to 1948. Toxaphene applications of 0.22 to 0.46 pound were made in 1949 and 1950. Some applications of DDT at 0.31 to 0.46 pound and of aldrin at 0.048 to 0.082 pound per acre were also made in 1950.

One of the duck clubs was sprayed with DDT at the rate of 1 pound per acre after the resistance tests had been made. This dosage was effective, but when the area was later resprayed with the same dosage it was ineffective. Application of 1.5 pounds of dieldrin per acre in this area was also ineffective.

In two lots of mixed *C. quinquefasciatus* and *C. tarsalis* larvae from Paloma field and from near Stockdale Road, 11 and 30 miles, respectively, from the duck-club area, resistance to DDT was only three times that of larvae from the untreated area, and no resistance to other insecticides was indicated.

C. quinquefasciatus larvae from various situations were tested during the summer

TABLE 3.—Analysis of water samples from areas in Kern County where *Culex tarsalis* larvae were developing.

Test	Pin Tail Duck Club	Ware Duck Club	Paloma Field	Poso Creek (Check)
pH	7.9	7.1	8.1	8.4
	Parts per million			
Bicarbonate	198	122.4	115	204.7
Carbonate	3	0	0	10.5
Hydroxide	0	0	0	0
Hardness (as calcium carbonate)	132	1138	55	127.5
Chloride	41.6	2060	9.6	614
Nitrate nitrogen	0			
Organic nitrogen	0.5	0.2	0.1	0.5
Sulphate	2.8	396	6.9	34.6
Phosphate	3.4	1.2	0.1	0.7
Calcium	38.2	223	20.8	37.6
Soluble iron	1.5	0.4	0.6	0.6
Magnesium	8.8	142	0.1	8.2
Manganese	0.1	1	0	0.2
Sodium (calculated)	59.9	1060	66.7	455
Total solids	395.4	4001.5	306.6	1399.2

and fall, but definite comparisons with untreated larvae could not be made because such larvae were not found in the Kings County untreated area or at the Firebaugh sewage plant, as anticipated. Larvae taken from a dairy drain at the McCuen Ranch in Kings County showed considerable resistance to toxaphene, DDT, lindane, and heptachlor. This dairy was found to have been treated every two weeks with benzene hexachloride. Lower resistance was indicated in larvae from a second drain in this area from a dairy that had been treated with DDT. Although Firebaugh is not in a control district, the larvae taken from the sewage plant appeared to have considerable resistance, and it was found that the water was occasionally treated with one of the chlorinated hydrocarbon insecticides.

C. quinquefasciatus larvae from the Visalia sewer farm showed considerable resistance to the insecticides tested. Benzene hexachloride, which had been used in control operations against these larvae, had failed just prior to these tests. A high resistance to lindane was also found in larvae from a cannery-waste pond in the Merced District, where this insecticide was no longer effective.

Mosquito-abatement managers in a number of districts in the San Joaquin Valley find that larvicide applications are less effective against *A. nigromaculis* in the late summer and fall than against larvae produced earlier in the year. In two of the untreated check areas only fractionally larger amounts of insecticides were required in the fall than in the spring except for a threefold increase in DDT in one area. The large increase in DDT may have been due to contamination of the area with this insecticide. The reduced effectiveness of larvicides in fall months which has been noted in control operations has been shown to be associated with alkali conditions in some areas. Other undetermined factors may also be involved.

Resistance to insecticides other than those used against them has been demonstrated in mites, mosquitoes, house flies, and *Drosophila*. In a review of the literature on insect resistance Babers and Pratt (1951) conclude in part,

"It is not possible apparently to cover all cases, but the following generalities begin to appear:

(1) A very high resistance to one insecticide confers a certain amount of cross tolerance for other insecticides of widely dissimilar nature.

(2) When the level of resistance is low, the resistance is almost specific and is limited to other insecticides of closely related structures.

. . .

(8) Once resistance to any insecticide is developed in house flies, the development of resistance to other insecticides proceeds at an accelerated rate."

The resistance of *C. tarsalis* in the Kern District has been of about the same general pattern. The high tolerance of these larvae for heptachlor is believed to represent the most extreme degree of resistance so far recorded in mosquitoes.

Failures that have already occurred with benzene hexachloride and lindane against *C. quinquefasciatus* larvae indicate that chlorinated hydrocarbon insecticides may soon become completely ineffective against this species in areas that are repeatedly treated.

Larvae of *A. nigromaculis* and *A. dorsalis* in the San Joaquin Valley, which are now partially resistant, will undoubtedly become very resistant to chlorinated hydrocarbon insecticides if they continue to be used against them. No estimate of how long this will take is possible on the basis of present information.

The high resistance developed in *Culex* larvae that were repeatedly treated and the rapid acceleration in the rate of resistance of *A. nigromaculis* in the Peacock-Canfield area, where newly hatched larvae were treated with DDT, indicates that resistance to chlorinated hydrocarbon insecticides may develop more rapidly in young larvae.

Summary—The resistance of several important species of mosquitoes in the San Joaquin Valley of California to DDT, toxaphene, lindane, and aldrin was deter-

mined in laboratory tests of larvae from treated and untreated areas. Tests were made in six counties in the Valley—Kern, Tulare, Kings, Fresno, Merced, and Madera.

Aedes nigromaculis larvae from the treated areas were found to be from three to seven times as resistant to DDT as larvae from the untreated areas. Resistance to toxaphene was less than twice that of larvae from the untreated area except in two areas, in which resistance was from two to three times that of the larvae from the untreated area. Little or no resistance to lindane and aldrin was shown except in one area in the Kern District, where it was twice that of the larvae from the untreated area.

In a few tests with *Aedes dorsalis,* resistance to DDT was 3 to 12 times that of larvae from the untreated area, but no resistance to the other insecticides was indicated.

Culex tarsalis larvae from a duck club in the Kern District, where applications of toxaphene and aldrin were failing, were found to be 10, 33, 11, 215, and 1300 times as resistant, respectively, to DDT, toxaphene, lindane, aldrin, and heptachlor as larvae from an untreated area. Larvae from a nearby duck club had a smaller range of resistance. Parathion was about equally effective on both treated and untreated larvae. DDT at 1 pound per acre was effective against these larvae in the first application and failed in the second. Dieldrin was ineffective at 1.5 pounds per acre.

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FURTHER OBSERVATIONS ON SEXUAL DIMORPHISM IN MOSQUITO PUPAE (DIPTERA, CULICIDAE)

By STANLEY J. CARPENTER[1]

Moorefield (1951) pointed out obvious structural differences in the sexes of mosquito pupae as exhibited by the structure of the tenth abdominal segment (genital pouch) which is attached to the sternite of the eighth segment and lies ventral of the paddle. Moorefield illustrates these sexual characters as observed in eight species of mosquitoes representing five genera studied as follows: *Aedes stimulans* (Walker), *A. trivittatus* (Coquillett), *A. vexans* (Meigen), *Anopheles punctipennis* (Say), *Culex apicalis* Adams, *C. restuans* Theobald, *Culiseta inornata* (Williston) and *Psorophora ferox* (Humboldt).

The writer has checked and verified this character for separating the sexes of mosquitoes in the pupal stage by examining both males and females with associated

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pupal skins of thirty-two species of mosquitoes occurring in North and Central America, representing thirteen genera. The following genera and species were examined: *Anopheles albimanus* Wiedemann, *A. aquasalis* Curry, *Toxorhynchites hypoptes* Knab, *Trichoprosopon digitatum* (Rondani), *Sabethes cyaneus* (Fabricius), *S. chloropterus* (Humboldt), *Wyeomyia scotinomus* Dyar and Knab, *W. arthrostigma* Peryassu, *W. personata* (Lutz), *Limatus durhamii* Theobald, *Uranotaenia geometrica* Theobald, *Culiseta incidens* Thomson, *C. maccrackenae* Dyar and Knab, *Orthopodomyia fascipes* Coquillett, *Psorophora ferox* (Humboldt), *Aedes taeniorhynchus* (Wiedemann), *A. euplocamus* Dyar and Knab, *A. leucocelaenus* Dyar and Shannon, *A. leucotaeniatus* Komp, *A. terrens* (Walker), *A. septemstriatus* Dyar and Knab, *Haemagogus spegazzinii falco* Kumm et al., *H. equinus* Theobald, *H. argyromeris* Dyar and Ludlow, *H. chalcospilans* Dyar, *H. lucifer* Howard, Dyar and Knab, *Culex mollis* Dyar and Knab, *C. quinquefasciatus* Say, *C. bihaicolus* Dyar and Nunez Tovar, *C. secundus* Bonne-Wepster and Bonne, *C. conservator* Dyar and Knab and *C. corrigani* Dyar and Knab.

The size of the tenth segment or genital pouch corresponds to the size of the genitalia of the adult male or female mosquito in question. The genital pouch of pupae examined for male mosquitoes differed in size according to the genera and species. In some *Culex* species the pouch was only about one-third as long as the pupal paddles, while in some other genera, particularly *Limatus,* it extended to the outer one-third of the paddles. In the males the pouch was always bifurcate to near the base, while in the females it was always shorter than in the males and broadly rounded, sometimes slightly indented posteriorly.

This sexual character can be seen quite readily in the living pupa by taking the specimen up in a transfer pipette as described by Moorefield and rotating the pipette into proper position and examining the specimen under a binocular dissecting microscope or a good hand lens. This means of sexing mosquito pupae is of considerable value when mosquitoes are being reared and associated with their exuviae for taxonomic studies.

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A FIRST RECORD OF *AEDES DIANTAEUS* H. D. & K. FOR MASSACHUSETTS WITH NOTES ON ASSOCIATED SPECIES [1]

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On April 1, 1951, in a kettlehole about three miles north-northeast of Westhampton, Massachusetts, many first instar larvae of *Aedes diantaeus* were collected with numerous other Culicine larvae. This species has never been reported from Massachusetts, nor has it been reported south of Dublin, New Hampshire, its type locality. Dyar (1928) reports the distribution as "Canadian forested region from N. H. and Ontario to British Columbia. The species is rare and local, frequenting

[1] Contribution of the Department of Entomology, University of Massachusetts, Amherst, Mass.

the darkest woods." A species collected in Belchertown, Mass., was thought to be *diantaeus* until the collections in Westhampton were made. Dr. Marion E. Smith of the University of Massachusetts has determined that the Westhampton specimens are *diantaeus* by comparing them with the type in Washington, D. C. The Belchertown specimens represent a new species which she is presently describing.[1] A single larva of the new species was taken with *diantaeus* in Westhampton on April 22.

During a period of a little more than a month (April 1 to May 6), all larval instars and pupae of *diantaeus* were collected, as well as larvae of 11 species of *Aedes, Mochlonyx culiciformis (karnerensis),* and *Culiseta morsitans.* All of the collections were made in the same pool. The abundance of the various species of *Aedes* in a month of larval collecting was as follows:

Present in great numbers: *excrucians, implacabilis, diantaeus, fitchii;* present in moderate numbers: *trichurus, canadensis, intrudens;* present in small numbers: *communis, punctor, cinereus;* single specimens taken: *stimulans* and a new species.

Larvae of *Mochlonyx culiciformis (karnerensis)* were extremely abundant and fed freely on the larval population, accounting in part for the decreased numbers of many species as the season advanced. *Culiseta morsitans* larvae were not common, but several were taken. An adult of *A. aurifer* was found on May 6, along with 2 adults of *diantaeus.* Many adults of the latter were reared in the laboratory, providing material for study. Thus a total of 15 species of Culicidae, 13 of them *Aedes,* were found in one small pool.

[1] Subsequently described as *A. pseudodiantaeus* Smith in Bull. Brook. Ent. Soc. XLVII(1):19–28. 1952.

The pool itself measures about 40 feet in diameter and 1 to 3 feet in depth in the spring, but is nothing more than soggy ground in late summer, at least during wet years. There is an abundance of cattails *(Typha latifolia),* sedges (Cyperaceae), and woody shrubs common to swampy, cool, woodland soils. These seem to create some variable conditions of shade and environment in different parts of the pool. Sphagnum is not present. The locality is of interest since it is in open woods about 100 feet from a roadway and, in addition, only at 500 feet elevation. *Diantaeus,* being a northern species, might be expected to occur at higher elevations in Massachusetts. The locality is characterized by scattered, mature white pines remaining from the hurricane of 1938, and a ground cover of young hardwoods and perennials, especially wild *Rubus.* The surrounding area is wooded, with occasional farms and meadows. Although the ketlehole has no outlet, a temporary stream runs just below, emptying into a large permanent stream some 150 yards distant.

In conclusion, *Aedes diantaeus* now has been found in Massachusetts, being both a first record for the state and a new southern limit in the distribution of the species. The locality from which it was taken is remarkable in the experience of local workers in that such a large number of species of *Aedes* occurs at the same time and in so small an area.

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ADDITIONAL SPECIES OF MOSQUITOES IN OKLAHOMA

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In 1942 Rozeboom (10) recorded forty species of mosquitoes in Oklahoma. In 1945 Roth (9) described *Psorophora longipalpis,* including records from this State. The present paper adds eleven species, bringing the State total to fifty-two recorded species. While this list is extensive, it is probably incomplete. Oklahoma exhibits considerable variety in physiography and climate, supporting highly diversified flora and fauna.

The collections were obtained from light traps operated by local cooperators throughout the State in the mosquito survey and control activities of 1945–1948. The new records came from thirty-seven of these traps (standard New Jersey type) in as many locations, each operated one season, usually April-October. Collection and identification of the specimens were made possible through the cooperation of the U. S. Public Health Service, the Oklahoma State Department of Health, and the University of Oklahoma.

Acknowledgments for their interest and support in this project are especially due to Dr. G. H. Bradley, Communicable Disease Center, U. S. Public Health Service; to Mr. H. J. Darcey, Bureau of Sanitary Engineering, Oklahoma State Department of Health; and to Dr. J. Teague Self, Department of Zoological Sciences, University of Oklahoma. Mr. John H. Bright and Mr. T. E. McNeel, Communicable Disease Center, and Mr. E. C. Warkentin, Division of Water Pollution Control, U. S. Public Health Service, facilitated much of the work in connection with the Arkansas-White-Red River Basins investigations.

The collections and literature of the United States National Museum were made available to the writer for reference purposes through the kindness of Dr. Alan Stone. Sorting of the light trap material was supported in part by a grant from the Alumni Development Association of the University of Oklahoma. The writer is also indebted to Mrs. Joyce Calkins Bales, Mr. Alex Burke, Mr. James Norman, and to many other students and assistants too numerous to mention here for their invaluable aid in various phases of the work.

* This paper results from collections made largely while the writer was on duty with the Communicable Disease Center, Public Health Service, Federal Security Agency, and the Oklahoma State Department of Health. Studies of these collections were continued as personal research at the University of Oklahoma and were recently extended on further duty with the Communicable Disease Center in connection with the Arkansas-White-Red River Basins investigations. Since comprehensive distributional studies have been interrupted by an assignment to foreign duty, the writer offers this preliminary note on the new State records at this time.

LOCALITIES

In the following list the light trap locations are grouped according to physiographic regions and approximately in geographic series from east to west across the State. The counties are shown in parentheses, followed by the year of trap operation. The list includes only the locations from which new State records were obtained, as noted, or about one-half of the light trap locations during 1945–1948.

OZARK PLATEAU (northeastern): — 1. Ketchum (Craig), 1947: *Aedes cinereus.* PRAIRIE PLAINS (northeastern): — 2. Nowata (Nowata), 1947: *Culex pipiens.* 3. Claremore (Rogers), 1947: *Culex pipiens.* 4. Eufaula (McIntosh), 1947: *Aedes dupreei, A. cinereus.* 5. Sallisaw (Sequoyah), 1946: *Aedes cinereus.* OUACHITA MOUNTAINS (southeastern): — 6. Broken Bow (McCurtain), 1946: *Aedes dupreei.* GULF COASTAL PLAINS (southeastern):— 7. Tishomingo (Johnston), 1946; *Urano-*

taenia syntheta. Arbuckle Mountains (south-central):—8. Platt National Park (Murray), 1948: *Aedes dupreei, A. tormentor, Uranotaenia syntheta.* Sandstone Hills (east-central):—9. Coalgate (Coal), 1947: *Uranotaenia syntheta.* 10. Ada (Pontotoc), 1945: *Uranotaenia syntheta.* 11. Shawnee (Pottawatomie), 1946: *Culex pipiens, Uranotaenia syntheta.* 12. Pawhuska (Osage), 1946: *Culex pipiens.*

Red Beds Plains (west-central and southwestern): — 13. Tonkawa (Kay), 1946: *Culex pipiens.* 14. Great Salt Plains (Alfalfa), 1946: *Culex pipiens.* 15. Alva (Woods), 1946: *Culex pipiens, Uranotaenia syntheta.* 16. Enid (Garfield), 1946: *Culex pipiens, Uranotaenia syntheta.* 17. Guthrie (Logan), 1948: *Aedes thelcter, Uranotaenia syntheta.* 18. Fort Reno (Canadian), 1948: *Aedes thelcter, Culex stigmatosoma.* 19. Lake Overholser (Oklahoma), 1946: *Aedes dupreei, Culex stigmatosoma, Culex pipiens.* 20. Anadarko (Caddo), 1947: *Aedes thelcter.* 21. Walters (Cotton), 1947: *Aedes thelcter, Uranotaenia syntheta.* 22. Hobart (Kiowa), 1948: *Anopheles franciscanus.* 23. Altus (Jackson), 1946: *Aedes mitchellae, Uranotaenia syntheta.* 24. Mangum (Greer), 1948: *Anopheles franciscanus.* Wichita Mountains (southwestern):—25. Medicine Park (Comanche), 1946: *Anopheles franciscanus, Culex thriambus, Uranotaenia syntheta.* 26. Quartz Mountain Park (Greer), 1948: *Anopheles franciscanus.* Gypsum Hills (western):—27. Hollis (Harmon), 1948: *Anopheles franciscanus, Aedes thelcter, Uranotaenia syntheta.* 28. Elk City (Beckham), 1948: *Anopheles franciscanus, Aedes dupreei, Culex stigmatosoma, Uranotaenia syntheta.* 29. Clinton (Custer), 1948: *Aedes thelcter.* 30. Watonga (Blaine), 1946: *Aedes dupreei, A. thelcter, Culex pipiens, Uranotaenia syntheta.* 31. Taloga (Dewey), 1948: *Anopheles franciscanus, Culex pipiens, Uranotaenia syntheta.* High Plains (northwestern): — 32. Cheyenne (Roger Mills), 1946: *Anopheles franciscanus.* 33. Shattuck (Ellis), 1948: *Anopheles franciscanus, Culex stigmatosoma, C. pipiens, Uranotaenia syntheta.* 34. Doby Springs (Harper), 1948: *Anopheles franciscanus, Culex stigmatosoma, Uranotaenia syntheta.* 35. Beaver City (Beaver), 1946: *Anopheles franciscanus, Culex pipiens.* 36. Goodwell (Texas), 1946: *Anopheles franciscanus, Culex pipiens.* 37. Boise City (Cimarron), 1946: *Culiseta incidens.*

New Oklahoma Records

Anopheles (Anopheles) franciscanus McCracken 1904. This species is distributed across the extreme western area of Oklahoma in the Red Beds Plains, Wichita Mountains, Gypsum Hills, and High Plains. It is sometimes associated in collections with *A. pseudopunctipennis* which occurs farther east in the State. *A. franciscanus* was collected occasionally in western light traps, usually with one or two specimens per collection, the highest being four. The accumulated records, too numerous to list, include ninety-four collections (20mm, 98ff) distributed seasonally as follows: May, 1 coll. (1m); June, 10 coll. (1m, 10ff); July, 27 coll. (8mm, 29ff); Aug., 25 coll. (3mm, 29ff); Sept., 27 coll. (6mm, 27ff); Oct., 4 coll. (1m, 4ff). These records are from Hobart, 25 coll. (8mm, 22ff); Mangum, 2 coll. (2ff); Medicine Park, 6 coll. (3mm, 3ff); Quartz Mountain Park, 3 coll. (3ff); Hollis, 3 coll. (1m, 2ff); Elk City, 11 coll. (1m, 17ff); Taloga, 12 coll. (2mm, 11ff); Cheyenne, 1 coll. (1f); Shattuck, 12 coll. (3mm, 14ff); Doby Springs, 8 coll. (1m, 14ff); Beaver City, 2 coll. (2ff); Goodwell, 9 coll. (1m, 8ff).

A. franciscanus has been reported from Colorado (5), New Mexico, Texas, and westward to the Pacific Coast (7). Vargas (13) distinguishes *A. pseudopunctipennis* var. *willardi* from *A. franciscanus* by egg and larval characters and considers the latter as probably being confined to California. Since the adults of these two forms seem indistinguishable, *A. franciscanus* is used here as generally accepted until further studies can be made of the immature stages of the Oklahoma species.

Aedes (Ochlerotatus) mitchellae (Dyar) 1905. The Oklahoma record of this species

is from Altus in the extreme southwestern Red Beds Plains. Only one male was taken in the combined collections of May 30–31, but the dissected terminalia of this specimen are clearly typical. This species has been reported from Texas (2, 11) to New Jersey in the Gulf and Atlantic Coastal States (2).

Aedes (Ochlerotatus) dupreei (Coquillet) 1904. Only six males (dissected) have been determined with surety in the Oklahoma collections. The species, although rarely taken, seems widely distributed across the State, with isolated records in the eastern Prairie Plains and Ouachita Mountains, the central Arbuckle Mountains and Red Beds Plains, and the western Gypsum Hills. Light trap collections were as follows: Eufaula, June 9 (1m); Broken Bow, May 30 (1m); Platt National Park, Aug. 15–17 (1m); Lake Overholser, June 9–10 (1m); Elk City, June 5 (1m); Watonga, Sept. 26 (1m). This species has been reported from Missouri, Arkansas (2), Texas (11), and throughout the southeastern States northward to New York and Iowa (2).

Aedes (Ochlerotatus) thelcter Dyar 1918. This species has been collected occasionally in Oklahoma in the central and southwestern Red Beds Plains and the western Gypsum Hills. The best series was obtained from Watonga: July 6 (5m), 7–8 (17mm, 16ff), 9 (1m, 3ff), 10 (1m, 13ff), 11 (12ff), 12 (1m), 13 (1f), 14–15 (1f), 18 (1f). Other Oklahoma records are from Guthrie, July 8–10 (1f); Fort Reno, July 9 (1f); Anadarko, June 5 (5ff), 8 (4ff); Walters, June 9 (1f), 12 (1f), 15 (1f), 18 (1f), 24 (1f); Hollis, June 6 (1f); Clinton, July 6 (1f). This species has been reported from Texas (7) and Florida (12).

Aedes (Ochlerotatus) tormentor Dyar and Knab 1906. Rozeboom (10) noted the difficulty of separating females of this species from those of *A. atlanticus,* but assigned his specimens to the latter species by association with larval determinations. He also suggested that both species might well occur in Oklahoma. The present record from the south-central Arbuckle Mountains is based on one male (dissected) taken Aug. 14 in Platt National Park. The terminalia are clearly determinative. This species has been reported from Arkansas, Texas, and the southeastern Gulf and Atlantic Coastal States (2).

Aedes (Aedes) cinereus Meigen 1818. The Oklahoma records of this curious species (the males having female-type palpi) are based on four males (dissected) taken at three locations in the eastern Prairie Plains and the border of the Ozark Plateau: Ketchum, May 15 (1m); Eufaula, May 6 (1m), 26 (1m); Sallisaw, May 17 (1m). This species has been reported from Arkansas (2), Colorado (5), and widely throughout the northern United States, Canada, Europe, and Siberia (7).

Culex (Culex) thriambus Dyar 1921. This species seems oddly isolated for one as commonly collected as it has been in the one location, Medicine Park, in the southwestern Wichita Mountains of Oklahoma. The records from this light trap are too numerous to list here, including fifty-nine collections (118mm, 36ff) of one to twelve specimens each: June, 1 coll. (1m); July, 8 coll. (8mm, 2ff); Aug., 20 coll. (46mm, 20ff); Sept., 15 coll. (43mm, 5ff); Oct., 13 coll. (18mm, 7ff); Nov., 2 coll. (2mm, 2ff). This species has been reported from Texas (3, 11).

Culex (Culex) stigmatosoma Dyar 1907. A most surprising find in the light trap collections is this west coast species which is abundant in one location in Oklahoma and apparently well distributed in the central Red Beds Plains and the western Gypsum Hills and High Plains. The best series was obtained at Elk City, where the species appeared in fifty-six collections (391mm, 596ff): June, 2 coll. (3mm); July, 10 coll. (9mm, 28ff); Aug., 30 coll. (181mm, 275ff); Sept., 13 coll. (170mm, 253ff); Oct., 1 coll. (28mm, 40ff). The largest collection was taken on Sept. 3 (65mm, 38ff). Other Oklahoma records are from Fort Reno, Aug. 18 (1f), Sept. 28 (1m); Lake Overholser, June 8 (1f);

Shattuck, Sept. 13 (1f), 14 (1f), 21 (1f), 24 (1f), 25 (1m, 1f), 26 (1m, 1f), 28 (1f), 29 (1f), Oct. 3–4 (1m), 6 (1f); Doby Springs, Sept. 14 (1f). This species has been reported from Texas (7), but this record may refer to *C. thriambus*. Dyar (4) placed the latter species in synonymy with *C. stigmatosoma*, and this was accepted by Matheson (7). The Oklahoma specimens of these two species are easily distinguished by coloration and the male terminalia. Other records are from California, Oregon, and Utah (7).

Culex (Culex) pipiens, Linnaeus 1758. Rozeboom (10) noted the difficulty of separating females of this species from those of *C. quinquefasciatus*, and pointed out the distinguishing characters of the male terminalia, but listed only the latter species from Oklahoma. The present records are based solely on dissected males, although many females are readily determinable by coloration. The numerous records include 128 collections (330 dissected males). These clearly indicate the distribution of *C. pipiens* completely across the northern length of the State, from the eastern Prairie Plains, through the central Sandstone Hills and Red Beds Plains, to the western Gypsum Hills and High Plains. This distribution parallels that of *C. quinquefasciatus* across the southern length of the State. Where the two species meet, there is some evidence of intergradation in the characteristic male terminalia and female coloration. The accumulated records are too numerous for publication here, but the seasonal trends may be shown as follows: May, 3 coll. (3mm); June, 12 coll. (23mm); July, 29 coll. (70mm); Aug., 32 coll. (51mm); Sept., 36 coll. (116mm); Oct., 15 coll. (66mm); Nov., 1 coll. (1m). The largest collection was from Shattuck, October 3–4 (26mm); 50 collections (162mm) were obtained from this locality. Other Oklahoma records are from Nowata, 2 coll. (2mm); Claremore, 5 coll. (6mm); Shawnee, 2 coll. (2mm); Pawhuska, 30 coll. (93mm); Tonkawa, 16 coll. (23mm); Great Salt Plains, 1 coll. (1m); Alva, 2 coll. (2mm); Enid, 13 coll. (31mm); Lake Overholser, 3 coll. (4mm); Watonga, 1 coll. (1m); Taloga, 1 coll. (1m); Beaver City, 1 coll. (1m); Goodwell, 1 coll. (1m). This species has been reported from Missouri, Kansas (2), and Colorado (5). Matheson (7) regards the species as the common house mosquito of eastern North America, Canada, the Pacific Coast, Europe, and southern South America.

Culiseta (Culiseta) incidens (Thomson) 1868. This western species was collected from the High Plains in the extreme western part of the Panhandle of Oklahoma. It has been taken only at Boise City, May 10–16 (1f); May 27–June 1 (1m); June 11–17 (2mm, 2ff). This species has been reported from Colorado (5), New Mexico, and the Rocky Mountain and Pacific Coast States to Alaska (3).

Uranotaenia syntheta Dyar and Shannon 1924. Numerous records of this species show it to be widely distributed across western Oklahoma, reaching toward the southeast, and sometimes in association with *Uranotaenia sapphirina*. It occurs in the southeastern Gulf Coastal Plains, the central Arbuckle Mountains and Sandstone Hills, the central and southwestern Red Beds Plains, the southwestern Wichita Mountains, and the western Gypsum Hills and High Plains. The species is usually no more than an occasional visitor to western traps, one to six specimens per collection. The accumulated records, including 112 collections (21mm, 157ff), are too numerous for more than a seasonal summary here: May, 7 coll. (1m, 6ff); June, 12 coll. (2mm, 16ff); July, 23 coll. (2mm, 33ff); Aug., 21 coll. (9mm, 20ff); Sept., 31 coll. (1m, 54ff); Oct., 14 coll. (5mm, 19ff); Nov., 4 coll. (1m, 9ff). Locality records are from Tishomingo, 1 coll. (1f); Platt National Park, 1 coll. (1f); Coalgate, 2 coll. (1m, 1f); Ada, 3 coll. (2mm, 2ff); Shawnee, 9 coll. (2mm, 11ff); Alva, 1 coll. (1f); Enid, 2 coll. (2ff); Guthrie, 1 coll. (1f); Walters, 1 coll. (4ff); Altus, 22 coll. (4mm, 34ff); Medicine Park, 34 coll. (10mm, 52ff); Hollis, 3 coll. (4ff); Elk

City, 6 coll. (6ff); Watonga, 7 coll. (2mm, 9ff); Taloga, 3 coll. (3ff); Shattuck, 2 coll. (3ff); Doby Springs, 14 coll. (22ff). This species has been reported from Texas (4, 11).

SUMMARY

Eleven species of mosquitoes are added to the list of forty-one species previously collected in Oklahoma. The new records are from light traps (New Jersey type) distributed in thirty-seven locations throughout the State, 1945–1948. Each trap was operated by a local cooperator through one collecting season, usually April-October. The added species are *Anopheles franciscanus, Aedes mitchellae, A. dupreei, A. thelcter, A. tormentor, A. cinereus, Culex thriambus, C. stigmatosoma, C. pipiens, Culiseta incidens,* and *Uranotaenia syntheta.*

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Reference may be made to the monographs by Dyar (1922 and 1928), King, Bradley, and McNeal (1942), Matheson (1944), and Carpenter, Middlekauff and Chamberlin (1946) for identification and general distribution of the species in this paper and extensive bibliographies. Substantial works have also appeared on the mosquitoes of Oklahoma (Rozeboom, 1942) and the adjoining states of Arkansas (Carpenter, 1941) and Texas (Randolph and O'Neil, 1944).

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REGIONAL DIRECTORS TAKE NOTICE

The Publications Committee and the Editor believe that the Regional Directors can help the Association materially by sending news items of their respective regions to Mosquito News. The Editor has been instructed to circularize the Regional Directors to remind them of this obligation. Please send us notices of interesting events, descriptions of new or unusual operations, and notices of personal achievements relating to mosquitoes and mosquito control in your region. All AMCA members can help the Regional Directors by calling their attention to items of the kind mentioned. The editorial staff will help prepare them for publication if you desire. Items in this category should be sent to William E. Bickley, News and Notes Editor, University of Maryland, College Park, Maryland.

PRE-HATCHING TREATMENTS WITH DDT LARVICIDES FOR THE CONTROL OF *AEDES TAENIORHYNCHUS* (WIED.) IN THE CANAL ZONE

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and

CHARLES M. KEENAN [2]

Madden *et al.* (1945) reported that DDT applied as an oil solution or an emulsion to ground litter and vegetation used as resting sites for *Aedes sollicitans* (Walker) and *A. taeniorhynchus* gave a reduction of adult mosquitoes for as long as two and one-half months in Florida. Wisecup *et al.* (1946) obtained satisfactory results by direct application of various forms of DDT larvicides applied at the rate of 0.2 lb. DDT per acre with hand equipment against the larvae of *A. sollicitans* and *A. taeniorhynchus* in Florida. Wisecup *et al.* (1947) found that in large scale applications of DDT sprays from airplanes as preflooding treatments in Florida, no control of saltmarsh mosquito larvae was obtained, but that direct application of DDT larvicides at the rate of 0.2 to 0.4 lb. DDT per acre gave satisfactory control of the larvae except in tall and dense vegetation.

Farfan Swamp, an area of approximately 1,200 acres, located just west of the Pacific entrance to the Panama Canal favors heavy breeding of *Aedes taeniorhynchus* at certain times during the year and presents a serious problem in nearby communities. This swamp is subject to some flooding with saltwater at high tide and frequent flooding with rainwater during the rainy season. Observations made during recent years by various mosquito control workers in the area indicate that heavy breeding of this species may be expected following the first heavy rains after the beginning of the rainy season.

On April 22, 1949, near the end of the dry season, four 2-acre plots were given pre-hatching treatments with DDT larvicides. Plots 1 and 4 were treated with 10 percent DDT in pyrophyllite applied with a rotary type hand duster at the rate of 2 lbs. DDT per acre. Plots 2 and 3 were treated with 5 percent DDT in fuel oil applied with a knapsack sprayer at the rate of 2 lbs. DDT per acre. Plots 1 and 2 consist of dense mangrove trees which had been killed by deposits of silt from canal dredging operations. Plots 3 and 4 consist of rather open grassy areas. Our controls were selected from other parts of the swamp, well-removed from the test plots.

Light rainfall occurred in the Farfan area during the week of May 8 to 14, with a very heavy rain falling during the night of May 14 and flooding most of the swamp. An inspection was made of the area on May 18, twenty-six days after the pre-hatching treatment, and the following observations were made:

Plot 1 and Control—Water was standing in large shallow pools in which moderate to heavy densities of fourth instar larvae and pupae of *A. taeniorhynchus* were present. Approximately 100 larvae could be obtained in a single carefully selected dip with a standard white enamel dipper. Numerous adult mosquitoes were seen resting on pupal skins after emergence. Ten percent DDT dust applied at the rate of 2 lbs. DDT per acre did

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not give any apparent reduction of *A. taeniorhynchus.*

Plot 2 and Control—Moderate densities of larvae and pupae of *A. taeniorhynchus* were present in water-filled cracks in the earth and in small pools. Five percent DDT in fuel oil applied at the rate of 2 lbs. DDT per acre as a pre-hatching treatment gave an estimated 50 percent reduction of *A. taeniorhynchus.*

Plot 3 and Control—Breeding of *A. taeniorhynchus* was light except for one small ditch in the test plot where larvae were present in moderate numbers. No apparent reduction was obtained when 5 percent DDT in fuel oil was used at the rate of 2 lbs. DDT per acre as a pre-hatching treatment.

Plot 4 and Control—Breeding of *A. taeniorhynchus* was light in both the test and control plots. No apparent reduction was obtained when 10 percent DDT dust was used at the rate of 2 lbs. DDT per acre as a pre-hatching treatment.

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GROUND SPACE SPRAYING OF *MANSONIA* AND OTHER MOSQUITOES IN LEESBURG, FLORIDA *

MAURICE W. PROVOST [1]

I. INTRODUCTION

Since the advent of DDT, a voluminous literature has appeared on the technique of adulticiding. Although hundreds of adulticiding techniques have appeared to be successful, there has been virtually no scientific appraisal of programs employing them. The 1948–1949 studies of the Florida State Board of Health in Leesburg were essentially an attempt to evaluate a program in which the mosquitoes were primarily *Mansonia,* and the method of control was to be the use of DDT thermal aerosols and mists.

Leesburg, a city of some 9,500 population, is in the lake and rolling hill region of central Florida. It occupies an isthmus separating lakes which have large sections of their shorelines in swamp or marsh (Fig. 1). Several of these embayments penetrate the city limits. They are typically peat or muck bays supporting extensive sawgrass *(Mariscus jamaicensis)* marshes and cypress *(Taxodium distichum)* swamps. The deep organic soils of both marshes and swamps hold extensive shrubby growths of willow *(Salix nigra),* buttonbush *(Cephalanthus occidentalis),* and water willow *(Decodon*

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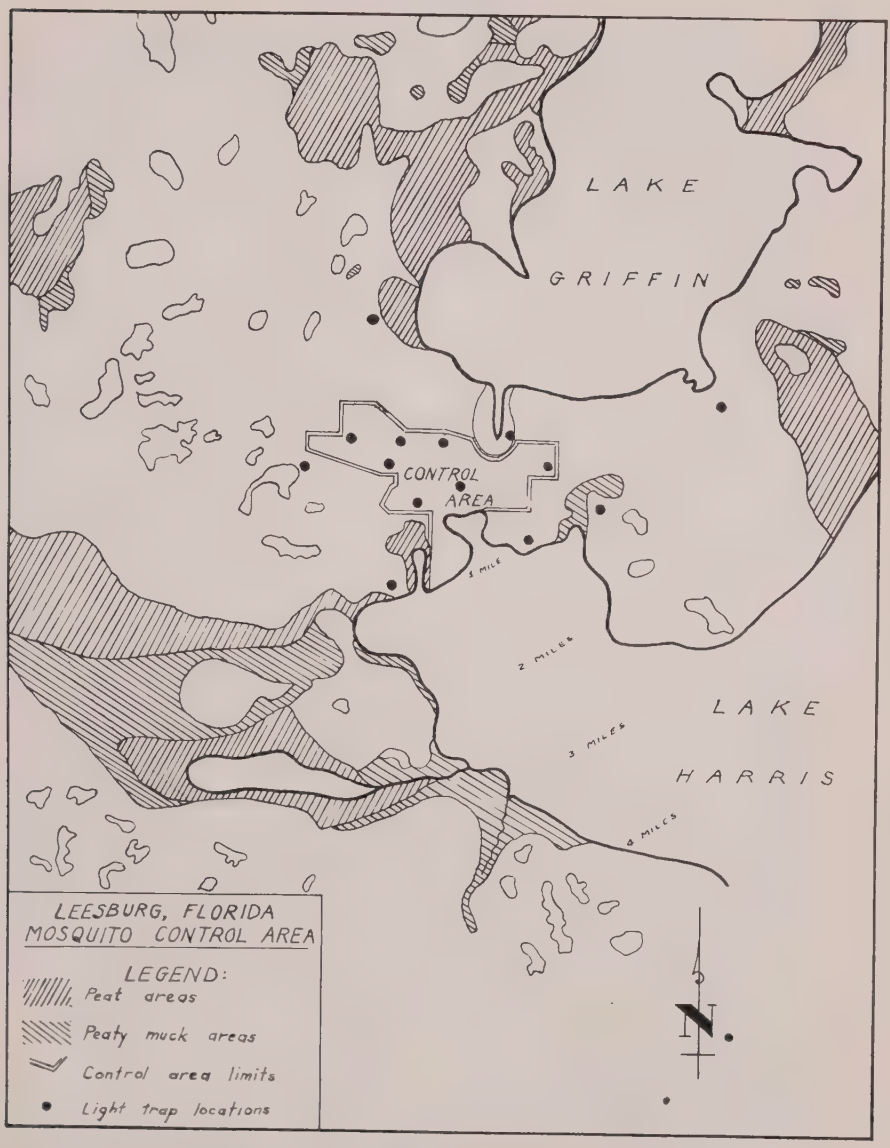

Fig. 1. Location of Leesburg with respect to water, swamps, and marshes. Both peat and peaty-muck soils support a great abundance of host plants for *Mansonia* spp. Map adapted from soil map of Lake County (U. S. Dept. Agric., Bureau of Soils; 1923).

verticillatus). The common emergent aquatics, particularly in the sawgrass, are arrowhead *(Sagittaria lancifolia),* pickerelweed *(Pontederia cordata),* cattail *(Typha latifolia),* and lizard's-tail *(Saururus cernuus).* Water hyacinth *(Piaropus crassipes)* is well distributed throughout. Water lettuce *(Pistia stratiotes)* is not as common as the hyacinth close to the city, but considerable communities of it occur in the cypress swamps. By contrast to these swamps and marshes, the northwestern sector of the Leesburg area is dotted with ponds, most of which are sand-bottomed, open, and grown to maiden-cane *(Panicum hemitomum),* spatterdock *(Nuphar advena),* and pickerelweed. This terrain produces *Anopheles crucians, Psorophora confinnis,* and *Culex* species, while the swamps and marshes described earlier produce the more important *Anopheles quadrimaculatus,* and, most especially, *Mansonia indubitans* and *Mansonia perturbans.*

From April through October in Leesburg, the maximum temperatures are in the nineties and the minima in the sixties. April and May are normally dry, but from June to October, expected rainfall would be six to seven inches per month. In the mosquito season, the relative humidity averages 60% at noon, 75% at 8:00 p.m., 98% at 3:00 a.m., and 85% at 8:00 a.m. In the evening hours, temperature inversions at ground levels seldom occurred over paved surfaces even as late as 10:30 p.m. Over vegetated surfaces, inversion conditions were attained usually by 8:30 p.m. An inversion difference of 1° C. between the one-foot and six-foot levels was attained once as early as 7:15 p.m., but on several occasions did not occur until after 10:30 p.m. The best hours for aerosol retention at ground levels, therefore, came normally after 10:00 p.m.

II. The Problem

A glance at Table 1 will reveal the very serious mosquito problem in this city. Its anopheline mosquitoes alone constitute a menace. Three species are common and nearly equally so: *Anopheles quadrimaculatus, A. crucians,* and *A. walkeri.* The domestic mosquitoes, *Culex quinquefasciatus,* are an ever-present nuisance. The glades mosquito, *Psorophora confinnis,* plagues the city after very heavy rains in summer and fall. But over and above all, Leesburg is harassed by *M. indubitans* and *M. perturbans.* This paper will deal primarily with comparisons of *M. indubitans, M. perturbans,* and *A. quadrimaculatus.* "All biting species" indicates exclusion of *Culex (Melanoconion)* spp. and *Uranotaenia* spp.

Mansonia indubitans: Extensive larval studies, using the Bidlingmayer trap (Bidlingmayer, 1950), failed to uncover breeding on any host plant in this area but water lettuce. Both mosquito and host occur here at the northern limits of their distribution, and being tropical species, are very sensitive to low temperatures. From 1944 to 1947, the winters were cold, and *M. indubitans* occurred as a relatively small brood in the fall. The subsequent two winters were mild, and the species occurred in both 1948 and 1949 as large broods every 90 to 100 days. Larval investigations showed clearly the development of these generations (Provost, 1950). These were the years of adult control herewith discussed. The winter of 1949–50 was colder, and the subsequent spring brood of *indubitans* was very small. There followed in 1950 the first abnormally low water levels in the swamps of the Leesburg area since 1941, which all but eliminated further breeding of *indubitans.*

Mansonia perturbans: Larval studies in Leesburg (Bidlingmayer, 1950) uncovered breeding of *M. perturbans* on a great variety of host plants. It was predominant, however, on water lettuce, water willow, sawgrass, lizard's-tail, and arrowhead. Adult and larval collections showed but one generation a year; in 1948 and 1949, the big emergences came in April and May (Provost, 1950). Following an extremely mild winter, there was an un-

Table 1.—Monthly Average Collections of Mosquitoes Outside the Control Area in Leesburg, Florida, in 1949. Only the 2 light traps which operated throughout the year are included; 20 species affecting man are included in the totals.

SPECIES	FEMALES PER TRAP NIGHT											
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
M. indubitans	3.44	38.86	129.61	207.59	146.93	138.43	171.26	172.68	310.86	248.48	107.94	14.88
M. perturbans		1.14	47.46	170.18	245.19	53.42	11.06	14.68	12.21	11.75	.13	
C. (Culex) spp.*	5.50	9.50	10.35	10.25	11.39	14.15	46.49	36.86	129.66	21.61	21.00	40.07
An. crucians	7.75	32.43	22.02	11.72	10.82	8.80	13.75	13.98	18.52	6.89	5.44	15.47
An. walkeri	5.13	18.50	42.00	16.61	7.19	14.97	23.04	20.00	9.57	3.05	5.00	17.59
An. quadrimac.	1.81	8.64	21.81	12.28	7.46	9.22	12.55	9.57	10.16	3.48	6.88	5.71
P. confinnis				.18	.08	.40	4.75	6.98	8.14	2.12		
A. mitchellae	.25	.21	.42	.30			.04	.34	.42	.02		
A. infirmatus						.02	.02	.18	.21	.05		
A. taeniorhynchus		.14			.03	.15	.20	1.29	.04	.19		
A. sollicitans						.05			.07			
A. vexans						.02	.21					
TOTAL	24.50	108.71	274.27	428.91	428.85	240.30	287.62	277.63	501.34	298.69	146.88	94.12

* *Culex quinquefasciatus, Culex salinarius,* and *Culex nigripalpus.*

usually severe annoyance in the spring of 1949; the cold spring of 1950 was followed by an abnormally small emergence. Larval studies demonstrated one dominant generation per year, a fact corroborated by adult collections throughout Florida over an 8-year period. A slight resurgence of numbers in the fall was also noted. McNeel (1932) reported two "definite peaks in abundance during the summer" in Zellwood, which the biology of the species indicates as possible. But this is the exception rather than the rule in Florida.

Anopheles quadrimaculatus: The malaria mosquito is abundant in this area. Among the many malaria-control projects in Florida during World War II, the one in Leesburg was among the least successful in maintaining low levels of the vector. There was a great abundance of *A. quadrimaculatus* prior to initiation of adult control in 1948, and they remain numerous outside the control area. They originate in very much the same semi-swamp areas which produce the *Mansonia* hordes.

Since the effectiveness of an insecticidal fog is proportional to the *duration* of contact between fog and mosquito, it is just as important to fog when the mosquitoes are most vulnerable to the spray as it is to fog when the aerosol is most likely to hug the ground. In 1949, light traps outside of Leesburg (Station 11) were arranged to make three collections per night, 7:00 to 10:30, 10:30 to 2:00, and 2:00 to 6:00. They were operated in this fashion 14 nights in May, 21 in July, and 21 in September. All species except *A. walkeri* were shown to be most active in the evening and least active at dawn. This was particularly true of the *Mansonias*. With *M. indubitans,* the percentage of nights' collections entering the trap before 10:30 was 68 in May, 61 in July, and 67 in September, or 65.0% (11,467 out of 17,634) for the 56 trap nights. (For substantiation, cf. Bradley and McNeel, 1935, and King et al., 1937). If mosquito kill were proportional to activity, it would appear that the mortality of these mosquitoes per hour would be four times as great before 10 o'clock as after. Unfortunately, it is not until after that hour that the aerosol operates at its best in hugging the ground.

III. TECHNIQUES USED

In 1948, the space spraying was done with a Tifa fog machine putting out a 5% or 10% solution of DDT in fuel oil. In 1949, the same Tifa used a 5% or 7½% DDT-oil solution. Late in 1949, a Buffalo Turbine was used also to put out a 1% DDT emulsion. The Tifa was set to discharge 40 gallons per hour and the turbine 80 gallons per hour. Both of these machines were arranged for one-man operation, i.e., one man drove the truck and operated the machine. The treatments were always made at night, usually beginning at dark and continuing until midnight in 1948 and until 2:00 or 3:00 a.m. in 1949. The Tifa covered the 1030-acre area in four nights in 1948 and in two or three nights in 1949. The turbine was never used alone to cover the whole area. Operating each in separate sections, the Tifa and the turbine together covered the area in two nights. The applications were made at intervals of from three days to three weeks, depending largely on the mosquito population. Since no larval control at all was done, the problem of reinfiltration was preeminent both in timing operations and in evaluating them. Data were kept on all operations, to include quantity of formulation used, miles traveled, hours of operating, etc. A considerable amount of weather data was gathered, although correlations with control results are too voluminous and not significant enough to warrant discussion in this paper.

The amount of control achieved was gauged by New Jersey light traps operating every night from April to November. Seven of these were run within the area of control. On the outside, as checks, there were never less than three traps in operation, and during most of 1949, there were many more. These traps all burned 60-watt frosted white bulbs. Biting rates were taken early in the experiment. They

were soon discarded because the data secured were numerically too small for satisfactory statistical analysis and because the considerable man-power requirements were not available. That biting rates would have yielded substantially the same information as the light traps is very likely (cf. Young, 1948). In evaluating techniques, caged mosquitoes may have been preferable, but again the man-power was not available, and furthermore, the caged mosquito results alone would have been valueless in evaluating the program. Actually, *any* evaluation of adult mosquito control in the field is bound to be statistically on very shaky ground because (1) all sampling methods known are selective, and because (2) we know virtually nothing of mosquitoes' behavior during 95% of their adult lives, a few anophelines and *Aedes aegypti* being notable exceptions. The unfortunate result is that the mosquitoes themselves can cause more variation among adulticiding results than all the variables of technique, equipment, and material we can array against them.

The method of computing reductions after treatments received careful attention and considerable research in itself. The outcome of these statistical tests can be summed up in the following points: (1) The "before" figure was an average of three nights previous to the treatment. (2) The "after" figures were expressed as percent increase or decrease from the "before" figure and were given separately for each of seven days following the treatment. (3) Whenever several traps or several treatments were averaged, the result was based not on averaging percentages of increase or decrease (Table 3), but on total mosquitoes involved (Table 2, Figs. 2 and 3). (4) The resulting reduction figures were not corrected for population trend assumed from trap collections on the outside of the control area since it was

Table 2.—Changes in densities of all biting female mosquitoes after ground fog and spray applications of DDT in Leesburg, Florida, in 1948 and 1949, based on the operation of seven light traps within the control area. Average densities for each of seven days following the treatments are compared with a three day average density previous to treatments and the results are expressed as percent deviations.

Species	Average Density Before Treatment	% reduction without ( ), % increase with ( ); days following treatment: 1	2	3	4	5	6	7
		TIFA 1948 16 treatments						
M. indubitans	20.08	60.0	70.4	62.8	35.9	12.1	(1.5)	6.0
M. perturbans	21.54	24.1	22.3	27.6	56.0	39.3	17.4	(44.5)
An. quad.	2.12	78.8	71.1	66.9	69.4	33.5	(6.4)	(21.6)
All biting spp.	58.56	44.5	51.5	46.0	39.7	24.2	16.8	14.3
		TIFA 1949 23 treatments						
M. indubitans	18.00	49.2	61.3	38.0	(16.5)	(29.7)	(16.3)	(18.8)
M. perturbans	25.72	33.6	33.6	26.0	2.6	23.1	8.8	26.9
An. quad.	1.40	65.4	80.2	58.4	33.8	23.0	26.2	1.1
All biting spp.	61.75	45.3	53.6	37.2	1.6	(7.9)	1.6	4.9
		BUFFALO 1949 10 treatments						
M. indubitans	24.20	48.6	41.6	25.3	(6.9)	(15.1)	(38.6)	(55.0)
M. perturbans *								
An. quad.	1.04	77.6	62.3	55.5	(4.4)	(2.8)	(48.8)	(50.5)
All biting spp.	65.62	47.0	52.3	42.4	31.5	2.0	19.0	(14.3)

* The Buffalo Turbine was not in operation during the *perturbans* season.

questionable whether results, thus corrected, would have been more valid.

IV. EVALUATION OF TECHNIQUES

The results of Tifa treatments for 1948 and 1949 are given in Table 2 and shown in Fig. 2. The reduction in all biting

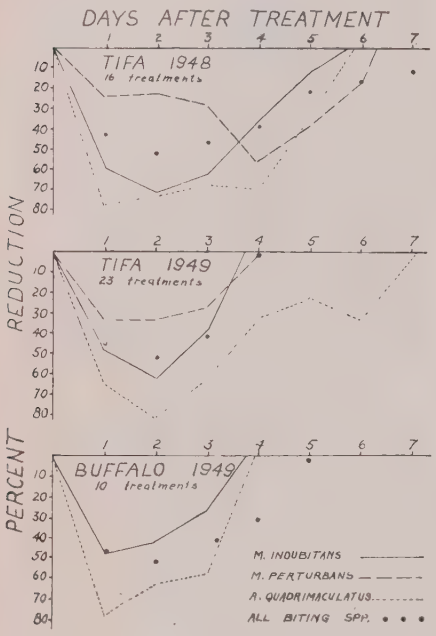

FIG. 2. Reductions in densities of female mosquitoes following ground spray and fog applications of DDT in Leesburg. Based on seven light traps in the control area. The horizontal lines represent average densities for three days previous to treatment.

mosquitoes for both years averaged slightly over 50%. When this reduction is divided among the several mosquito species, however, important variations are evident. *Anopheles quadrimaculatus* was consistently reduced more than any other species, averaging a little over 80% for the two years. Since the main biological factor affecting the reduction rates was probably re-infiltration of the fogged area, it would be expected that the mosquito with the least flight range would show the best control, and this would be *A. quadrimaculatus*. Should this be the true explanation for the good results with that species, the same reasoning would indicate the *Mansonias* to have the greatest flight range of the important mosquitoes in Leesburg. As between *perturbans* and *indubitans*, the poorest results were obtained with *perturbans* in both years, and aside from the possibility of flight range effect, the reason may also be that *perturbans* breeding is more widely distributed and closer in than the *indubitans* breeding.

Reductions following Buffalo Turbine treatments in 1949 compare favorably with fogging results in 1948 and 1949. As with the Tifa, the best reductions were obtained with *A. quadrimaculatus*. Because the turbine was not used early in the season, results with *M. perturbans* are not available. In the case of *M. indubitans*, a reduction of about 50% was achieved, the same figure as for all biting species combined.

If it were possible to delete from our figures the infiltration factor, the resulting reduction would be somewhere between the 50% for all species and the 80% for *A. quadrimaculatus*. In an investigation of 25 Tifa foggings in Illinois, each covering an area similar in size to Leesburg, Clarke (1948) reported an actual kill of 69% of the caged adult mosquitoes. The Leesburg data suggest an actual kill of about the same order.

Under the conditions prevailing in Leesburg in both 1948 and 1949, adulticide treatments resulted in substantial reductions for three to four days. In other words, it took that many days for an area of about 1100 acres, surrounded by unchecked breeding, to become reinfested with mosquitoes. When mosquitoes were emerging in large numbers, either *Mansonia* or *Psorophora*, there was frequently no significant reduction in adult numbers following treatments. At such times even semi-weekly treatments gave poor results. During lulls in mosquito emergence, treatments two weeks apart appeared adequate. It was obvious, both from the reductions

obtained and from population trends on the outside of the control area, that a rigid routine of treatments, whether weekly or semi-weekly, would have been either inadequate during periods of maximum emergence or wasteful during lulls in mosquito production.

Under Leesburg conditions, the dosage of DDT was best presented in pounds per mile of itinerary. In 1949, the Tifa discharged on an average 5.2 pounds per mile and the turbine 2.0 pounds per mile. The best approximation would be, respectively, 0.29 and 0.11 pound per acre. Using the Tifa data, because it was more abundant and representative, it is seen that at dosages of less than 5.0 pounds per mile or roughly 0.3 pound per acre, the results were erratic; above these dosages they were consistently satisfactory. With the turbine, the dosages used were never great enough to bring out a point above which consistently good results were obtained. The overall results demonstrated that even in a wide open Tifa, driven at five miles per hour, a 5% DDT solution is inadequate; while in a turbine discharging 80 gallons an hour at the same speed, a 1% emulsion is not adequate. The Leesburg studies indicate that a Buffalo turbine should be operated at a vehicle speed of five miles per hour, discharging 125 gallons per hour of a 2½% DDT emulsion. If the itinerary is so planned that there are 12 acres treated for every mile of front, the theoretical dosage (i.e., computed as discharge) will be .44 pound of DDT per acre.

For a Tifa operating at five miles per hour and discharging 40 gallons per hour, an 8% DDT solution would seem indicated. At this discharge rate, Tifas usually produce a fog with particles of about optimum size for aerosol control of adult mosquitoes. Because of the unpredictable dispersion of aerosols out of doors and also because of the variation in block dimensions in cities, swath-width means precious little with this technique. Instead, an effort should be made to plan the itinerary so that every mile of travel will cover 12 acres of terrain. At a speed of 5 m.p.h., this should represent a discharge of .44 pound of DDT to the acre. This dosage is not as heavy as it appears when it is remembered that only 1.4% of the discharged insecticide will be deposited for every 100 feet of swath width (Yeomans, 1950). Clarke (1948), after extensive tests with Tifas, decided that an 8% solution of DDT in oil at the rate of .3 pound of DDT per acre was minimum for consistently good results,—which is essentially like our findings in Leesburg. The Bureau of Entomology and Plant Quarantine (Yeomans, 1950) recommends 500-foot swaths and ½ pound of DDT discharged per 100 feet of travel. This is the theoretical equivalent of .44 pound per acre. Although approaches to the problem may differ, we are substantially in agreement with Yeomans (1950), with Clarke (1948), and with our own findings in Leesburg when we suggest for Tifas:

(1) 65 lbs. DDT per 100 gals. oil (approximately 8%)

(2) 40 gals. per hour discharge (approximately 20-micron m.m.d.)

(3) 5 miles per hour speed

(4) 1 mile of front per 12 acres treated (approximately .44 lb. DDT/acre)

The last requisite could be met in any number of ways, e.g., by fogging one or two sides of a block, by doubling or tripling traverses, by skipping half-blocks, etc., etc. And of course, requisites (1) and (3) could also be varied to affect (4). Requisite (2), however, should be varied only under extremely well-considered circumstances.

V. Evaluation of Program

The experience of two years in Leesburg has amply demonstrated how very difficult it is to obtain an accurate measurement of space-spraying control results. Except in those rare cases of phenomenal reduction of mosquitoes from phenomenal numbers, public reaction is an exceedingly poor criterion of control achieved. In view of the fact that laymen in Leesburg expressed general satisfaction with the control program of 1948 and 1949, it becomes

doubly interesting to consider the demonstrated, objective facts in the case. We find that the results varied greatly in three directions: with species of mosquito, with locations, and with treatments.

(1) *Species variation.* Reductions were far better with *A. quadrimaculatus* and other anophelines than with *Mansonia* and other culicines. They were much more satisfactory with *M. indubitans* than with *M. perturbans.* All analyses of species differences led to the same conclusion, viz., reductions were more satisfactory the more sedentary the species. (2) *Location variation.* There was no consistent pattern to the differences in reductions among the seven light-trap locations. The differences among these stations are clearly evident in Fig. 3. The mosquito species is seen to be the controlling factor. For *A. quadrimaculatus,* there were striking differences between stations only after the third day, for *M. indubitans* only the first day was without significant differences, while *M. perturbans* showed enormous differences throughout the post-treatment period. As

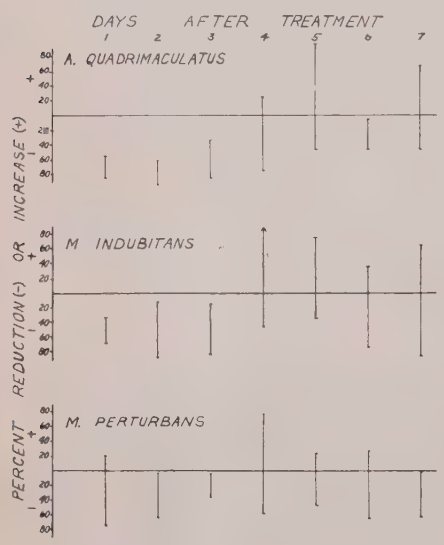

FIG. 3. Daily ranges of percent deviations in female mosquito densities for seven light traps in the control area. As in Fig. 2, the deviations are from three-day averages previous to treatment. Data based on twenty-three foggings in 1949.

with species variation mentioned earlier, this demonstrates the adaptability of space control methods to sedentary species and their erratic results with migratory species. (3) *Treatment variation.* This third variant was the greatest of them all. Consistent results were obtained only with anophelines. As stated earlier, all averages in this paper are for traps taken together and treatments taken together as though there had been but one trap and one treatment. Variations among trap locations and treatments were such that there was no alternative. It is readily seen in Table 3 that very few significant averages can be obtained from series of individual treatment results. So great is the variation in results among treatments that one treatment alone yields no significant information while even averaging ten treatments yields dubious information. The second day after treatment gave most of the significant averages; beyond the third day, significant averages were rare.

This variation in three dimensions has been reiterated to emphasize the necessity of evaluating a control program in terms of averages which consider all variables. An effective technique alone cannot guarantee a successful program.

It is very obvious from Fig. 4 that every treatment made a dent in the mosquito population. The average dent represents a 68% reduction from peak to lowest subsequent point and lasted three days. This evaluation thus parallels that already made for the technique, but the graph shows what the latter evaluation did not, viz., the significance of these reductions in the overall mosquito-density picture. It has long been judged that light-trap catches greater than 24 females per night indicate an annoyance. The State of New Jersey has even contemplated a lower figure. Using the arbitrary figure 24, it is seen that the Leesburg area was out of control virtually the entire season. The 1948 data are, incidentally, almost identical to the 1949 data depicted. The simple conclusion is that the dents in the mosquito population resulting from fogging were neither deep enough nor broad enough.

Table 3.—Average reductions in light trap collections of female mosquitoes. Results of individual treatments (i.e., % increase or decrease) are averaged rather than total samples as in Table 2. Only significant averages are given, with standard errors.

Species	Per cent reduction after treatment: 1st day		2nd day		3rd day	
			TIFA 1948 16 treatments			
M. indubitans	44.4	±10.03	57.4	± 9.42	51.9	± 9.94
M. perturbans						
An. quad.	80.7	± 4.29	75.6	± 5.64	74.1	± 4.88
All biting spp.	46.4	± 3.65	52.4	± 6.91	46.5	± 8.41
			TIFA 1949 23 treatments			
M. indubitans			44.0	±13.62		
M. perturbans			41.5	±10.17		
An. quad.	64.3	± 8.99	87.7	± 3.53	64.5	± 8.43
All biting spp.	41.4	± 6.23	56.7	± 5.04	32.7	± 8.34
			BUFFALO 1949 10 treatments			
M. indubitans						
M. perturbans						
An. quad.			87.5	± 6.00		
All biting spp.						

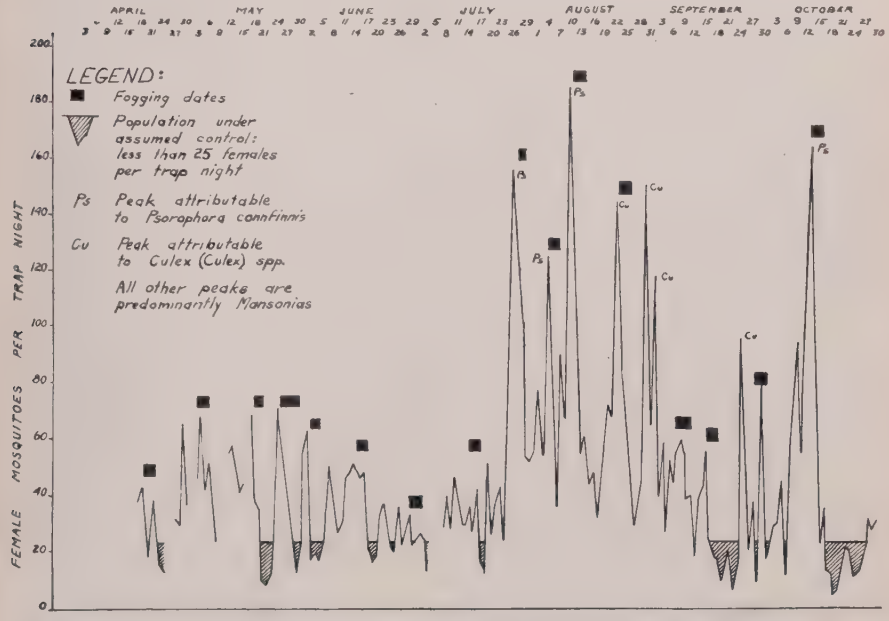

Fig. 4. Daily average collections, all biting female mosquitoes, for seven light traps in Leesburg control area in 1948. Showing relation to aerosol adulticiding program.

Statistical analysis of the voluminous Leesburg data bring out these further considerations: (1) The traps outside the control area showed the same number of reversals in density trend as those inside; connecting the peaks in Fig. 4 would, therefore, not present what the situation would have been without control. (2) Mean percentage deviation in outside and inside traps did not significantly differ; in other words, natural fluctuations in mosquito density were as great as fluctuations produced by control. (3) The percentage of collections with less than 25 mosquitoes in 1947, without control, did not differ significantly from the 1948 and 1949 figures. Even assuming greater mosquito production in 1948 and 1949, it is difficult to demonstrate how the fogging in these two years materially affected the seasonal mosquito-prevalence picture. All the satisfaction left is in the dubious conclusion that an average fogging reduced the mosquito hordes by some 50% for three or four days.

If mosquitoes are numerous enough to be an annoyance, surely an adequate control program should aim at something better than eliminating half of them some of the time. For the malaria mosquitoes in Leesburg, the average reduction was 80%, which is more in line with the expected and does speak very well for the technique in itself. If the other mosquitoes, representing the overwhelming majority, were either flying in or being produced in such numbers as to bring the average reduction down to only 50% for three or four days, it would seem that antimosquito measures other than adulticiding are indicated. In short, it is felt that the mosquito situation in Leesburg called for more than exclusive reliance on adulticiding.

There is some indication that these Leesburg findings may apply to any kind of space spraying under conditions of more or less continuous production of migratory mosquitoes. In Florida, the only serious mosquito pest which is always cyclical in production is the glades mosquito, *Psorophora confinnis*. Although the salt-marsh mosquitoes, *Aedes taeniorhynchus* and *Aedes sollicitans*, are normally produced in cycles or broods, there are many instances of continuous production over wide areas. For example, in Brevard County, salt-marsh mosquito broods succeeded one another so closely in 1948 that the vast breeding over the county's 50,000 acres of marsh could justly be called continuous. Aerial sprayings, with 5% DDT in oil at two quarts per acre, were three times as frequent as foggings in Leesburg. The average 24-hour reduction for 5 treatments, gauged by landing rates at 12 stations, was 45.9%. In Leesburg, 24-hour reductions, gauged by light traps, were 44.5%, 45.3%, and 47.0% respectively for Tifa foggings in 1948 and 1949 and Buffalo Turbine spraying in 1949 (Table 2). In both Brevard County and Leesburg, the reductions lasted three to four days. Experience in other sections of Florida (e.g., Lieux and Braddock, 1951) substantiates the evidence from these areas. It is thus concluded that where mosquito production in Florida is at all continuous and dominated by migratory species, exclusive reliance on adulticiding is unsatisfactory.

VI. SUMMARY

A mosquito-control program in Leesburg, Florida, was evaluated in 1948 and 1949. The mosquitoes were predominantly *Mansonia* spp. The only control method employed was space spraying with DDT from the ground. The evaluation was made with New Jersey light traps. Reductions varied with mosquito species, with trap locations, and with individual sprayings. The overall conclusion was that the average spraying reduced the mosquito population by about one half, this reduction lasting three to four days. Exclusive reliance on adulticiding was judged unsatisfactory in any Florida mosquito control program where mosquito production is continuous and dominated by migratory species.

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MANSONIA INDUBITANS DYAR AND SHANNON IN PANAMA [1]

By STANLEY J. CARPENTER [2]

The females of *Mansonia indubitans* Dyar and Shannon are difficult to separate from those of *M. titillans* (Walker) unless the specimens are boiled in potassium hydroxide and the pattern of spines on the eighth abdominal tergite is examined under a microscope. Due to this tedious procedure necessary for accurate identification, *M. indubitans* has not generally been recognized in many areas in which it undoubtedly exists. Thus the distribution of *M. indubitans* and its relative abundance in relation to populations of *M. titillans* is not generally known.

Mansonia indubitans has been recorded in the literature from the following areas: BRAZIL—Several localities in central Brazil (Dyar and Shannon, 1925 and Shannon, 1934); PERU—Iquitos (Shannon, 1934); MEXICO—Mata Cabestra in Vera Cruz Province (Martini, 1935); BRITISH HONDURAS—Blue Creek and Rio Cacao (Martini, 1935); PUERTO RICO—Lake Cartegena (Tulloch, 1937), Fort Buchanon and Camp Tortuguero (Pratt, 1945); JAMAICA BWI—Clarendon Parish (Pratt, 1945); FLORIDA—Avon Park, Fort Pierce and Boca Raton (Chamberlain and Duffey, 1945), Boca Raton (Pratt, 1945); BOLIVIA—Several localities in the departments of Santa Cruz, Chuquisaca, Beni, Cochabamba, La Paz and the territory of Colonias (Cerqueira, 1943); PANAMA—Buena Vista, La Jolla 2, Cerro La Victoria and Juan Mina (Galindo *et al.*, 1950).

Galindo *et al.*, (1950) point out that the number of *M. indubitans* taken in connection with forest mosquito studies in Panama was undoubtedly much greater than is shown since time was generally not taken to separate them from *M. titillans*.

The localities that were trapped are as follows, with the number of *M. titillans* and *M. indubitans* captured in each. The types of traps are indicated by the symbols LT (light trap), HBT (horse-baited trap) and HC (hand catch).

La Jolla, Republic of Panama: *M*

[1] Contribution from the Sixth Army Area Medical Laboratory.

[2] Colonel, MSC, 6th Army Area Medical Laboratory, Fort Baker, California.

titillans 504, *M. indubitans* 125 (HBT, LT, HC). Fort Clayton, Canal Zone: *titillans* 93, *indubitans* 0 (HBT). Fort Kobbe, C. Z.: *titillans* 0, *indubitans* 1 (HBT). *Gamboa,* C.Z.: *titillans* 20, *indubitans* 1. Fort Gulick, C.Z.: *titillans* 149, *indubitans* 0 (HBT). Fort Davis, C.Z.: *titillans* 66, *indubitans* 0 (HBT).

The specimens were boiled in potassium hydroxide and the pattern of the spines on the eighth abdominal tergite was observed; however after some practice the species could be separated by the length of the palpi. The highest incidence of *M. indubitans* found in these collections was at La Jolla 2, R. P. on the Pacific side, where its number was about one-fifth that of *M. titillans,* while in other localities it only occurred in small numbers when present. Although only 115 specimens were examined from the Atlantic side of the Isthmus (Fort Gulick and Fort Davis), it is interesting to note that not a single specimen of *M. indubitans* was found.

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VECTOR CONTROL SPECIALISTS

Opportunities in California with the State Department of Public Health. Several vacancies with salary ranging from $5,232 to $6,360. Qualifications are four years of full-time paid experience in sanitary or public health engineering or in entomology, including two years of experience in vector control. (One year of graduate work in sanitary or public health engineering, entomology or parasitology may be substituted for one year of nonvector control experience.) Also required is education equivalent to graduation from college with specialization in engineering or the biological sciences. Employment is in Berkeley and travel may be required. Write for details and application to State Personnel Board, 1015 L Street, Sacramento 14.

NEWS AND NOTES

Dr. Marston Bates of the Rockefeller Foundation gave the Invitational Public Address of the Entomological Society of America on the evening of December 12, 1951 in Cincinnati. Entomologists regard this as a distinct honor. The subject of Dr. Bates' talk was "Mosquitoes and Yellow Fever." He described and illustrated some of the work at the Villavicencio (Colombia) laboratory.

Public Health Reports is now a monthly journal in which have been amalgamated several other Public Health Service technical periodicals including the CDC *Bulletin*. "The pages . . . will be open to responsible authors, outside as well as within the Federal service." The first number of the revitalized publication contains two articles of interest to mosquito control workers, namely, "Susceptibility of *Anopheles quadrimaculatus* to Korean vivax malaria" by Martin D. Young and Robert W. Burgess, and "Aquatic invertebrates as indicators of stream pollution" by Arden R. Gaufin and Clarence M. Tarzwell.

The original predecessor of *Public Health Reports* was a "Bulletin" issued by the Marine-Hospital Service in 1878. Early bulletins recorded the great Mississippi Valley yellow fever epidemic that claimed 20,000 lives. The sternwheeler, *John D. Porter,* moving upriver from New Orleans to Vicksburg, Louisville, Cincinnati, and Pittsburgh, left an infected wake as authorities tried hopefully but futilely to kill it with carbolic acid.

The Eruption of the Hibok-Hibok volcano on Camiguin Island in the Philippines did not bring about an increase in malaria, according to Dr. Francisco J. Dy, WHO Regional Malaria Adviser for the Western Pacific.

The Florida State Board of Health has

The importance attached to mosquito control activities by the Health Department of one of our largest cities is attested by the accompanying photograph of the Los Angeles City Health Department exhibit at the annual meeting of the American Public Health Association, which was held October 29–November 2, 1951 in the Civic Auditorium in San Francisco.

issued a statement of "Policy . . . Pertaining to Present Mosquito Control Practices and Recommendations for a Long-Range Plan to Bring About More Effective Control in the State." The State Board of Health emphasizes the fact that the mosquito problem varies from place to place in both type and urgency. There may be health hazards or comfort hazards. Although locally acquired malaria has disappeared from Florida, *Anopheles quadrimaculatus* is probably as abundant in the state as it has ever been. However it is believed that an incipient outbreak of malaria could be quickly brought to an end. *Aedes aegypti* is not so abundant in large cities as it was a few decades ago. Anti-*aegypti* programs are encouraged. The numbers of *Culex quinquefasciatus* are an excellent index to community cleanliness. Many Florida species which are usually thought of merely as pest mosquitoes are potential vectors. The Board does not take any alarmist views in this matter, but it believes that control of these mosquitoes is properly a concern of public health agencies.

No mosquito control program can be efficient unless the following facts are known: (1) choice of breeding sites, (2) conditions for hatching and emergence, and (3) dispersal habits. There is a great deal of biological information which is lacking. Applications and limitations of control techniques and tools must be investigated. The Board believes that more emphasis should be placed on environmental and eliminative control measures and that adulticiding should be reserved as an emergency technique.

THE FIFTH ANNUAL MEETING of the Virginia Mosquito Control Association was held on January 7, 1952 at the Hotel Chamberlin, Old Point Comfort. Mr. Jonathan S. Gibson of Hilton Village was the presiding officer and Mr. Perry W. Ruth of Norfolk served as Chairman of the Program Committee. A full program of talks by state and local workers and officials of the Army, Navy, Air Force, Public Health Service, and Bureau of Entomology and Plant Quarantine was arranged. A feature of the afternoon session was a panel discussion on hydraulic fills. Robert L. Vannote acted as Chief Judge. Dr. L. H. Denny of Portsmouth is the newly elected president.

THE TWENTIETH ANNUAL CONFERENCE of the California Mosquito Control Association was scheduled for February 13, 14, and 15, 1952 at Fresno State College. Various aspects of the use of insecticides constituted the subject of one afternoon session. A morning session was devoted to discussions of "Mosquito Source Reduction." Mr. Ted Raley acted as Program Chairman and Local Arrangements were in charge of Mr. Ed Davis.

CULICIDOLOGY. The University of Massachusetts is among those institutions offering graduate courses on mosquitoes. The course is conducted by Dr. Marion E. Smith and was first given in 1948. Its scope is similar to the courses at Texas and Maryland. The importance of mosquitoes and the mountain of facts accumulated through the years certainly warrant courses in Culicidology in our colleges and universities, and I hope other schools have such courses.—Gordon Field.

CORRECTION. Fasc. 194 of the Genera Insectorum, Edward's Culicidae, is priced at about $40.00. The incorrect amount reported in the December NEWS was due to a misunderstanding in the rate of exchange of the Belgian franc.

FIELD TEAM TAKING BLOOD SMEARS and examining children and babies for enlarged spleens visits an area to be sprayed in 1952 (Mae-Rim District, Chiengmai, Thailand, June 1951). left to right, Dr. Udaya Sonthinand, Deed Thurman, and field team leader Nai Uivatana. The baby has a No. 5 spleen.

EDITORIAL

THE INFANTRY

In spite of all advances in equipment and techniques for aerial warfare, the infantry continues to be an indispensable force in war. But infantry equipped with flintlock muskets and old fashioned pistols would not now contribute much to victory on the battlefield. Neither would a company of foot soldiers, fully equipped with all modern weapons, be of much account if they had no knowledge of how to use them. Nor could the offices or officers of procurement and supply be considered to be discharging their duties if they did not keep fully abreast of the latest technical developments, so that the troops would be continually armed with the latest in both knowledge and equipment.

In mosquito control the same principles apply. Few will deny that the airplane has come to stay in mosquito control, but it is just as true that the successful anti-mosquito campaign sooner or later falls back on the ground forces, and that often the ground forces alone by winning countless isolated individual battles may put over the campaign all by themselves.

The air-arm often does not even exist or can be brought into operation only in rare emergencies.

It is all the more necessary therefore, for efficient mosquito control, that the ground forces be thoroughly informed, and be kept strictly up to date in equipment.

Therefore, the American Mosquito Control Association, recognizing its responsibility to the profession and to its constitution as an educational force, has caused to be prepared a new bulletin entitled "Ground Equipment and Insecticides for Mosquito Control."

The importance of this bulletin can hardly be overstressed. It will be a milestone in the progress of mosquito control, and *Mosquito News* confidently predicts that from the moment of its publication it will be held by all mosquito control workers to be as indispensable as the equipment it describes, the formulations it outlines and the information it summarizes. It will also serve to inform the general public, health officers, and community leaders of the advances in modern mosquito control methods and the necessity for keeping the workers supplied with the proper equipment. It will encourage communities to undertake mosquito control, and will help them to know how to go about it.

With the publication of the Ground Spray Bulletin, the Mosquito Control Infantry will again come into its own.

REVIEWS AND ABSTRACTS

Anopheles-BEOBACHTUNGEN IN SÜDRUSSLAND (*Anopheles* OBSERVATIONS IN SOUTH RUSSIA). W. Eichler. Riv. di Malariol. 30(1):29–38. 1951. The author reports his observations on the anopheline population of South Russia (Kuban district) made during 1943. The extensive swamps offer breeding places with high anopheline density, in spite of the well-organized malaria control work carried out before the 2nd world war by the Soviet Government. Characteristic of those areas are the lowlands flooded by the waters of the big rivers and covered by a rich growth of vertical and horizontal vegetation.

The most common *Anopheles* mosquitoes are: *messeae, typicus* and *atroparvus,* particularly *messeae.* The eggs of the Kuban *A. messeae* are slightly different from those of Central Europe. In the suitable areas oviposition occurs during the whole summer, but there are places, as the Tamen peninsula, where during the hot season every breeding place is dried up. Mosquitoes then cease to lay eggs and have only occasional blood meals. The author calls this period "the summer phase" and points out its importance for the epidemiology of hot areas. A count of anophelines in dwelling places showed that the outside limits of the villages are the most haunted.

In the breeding of larvae it was observed that the first to develop were always males, followed by mixed males and females; at the end of the breeding period there were only females.—From author's English summary.

NTAYA VIRUS. A HITHERTO UNKNOWN AGENT ISOLATED FROM MOSQUITOES COLLECTED IN UGANDA. Smithburn, K. C., and A. J. Haddow. Proc. Soc. Exptl. Biol. and Med. 77:130–133. 1951. A filterable neurotropic virus was isolated from mice inoculated intracerebrally with a mixed lot of mosquitoes captured in western Uganda. The agent is believed to be hitherto unknown and has been named Ntaya virus in respect of the locality in which the mosquitoes were caught. Certain of its pathogenic and immunological properties are discussed.—Authors' summary.

TRES ESPECIES NUEVAS DE *Aedes* (DIPTERA, CULICIDAE). Vargas, Luis, and Wilbur G. Downs. Rev. Soc. Mex. Historia Natural 11(1–4):161–172. 1950. The authors describe the larvae, pupae and adults, including male genitalia, of *Aedes* (*Ochlerotatus*) *shannoni* n. sp., *Aedes* (*Gualteria*) *ramirezi* n. sp. and *Aedes* (*Gualteria*) *kompi* n. sp. All of the above material was collected in the State of Morelos, Mexico, in a neotropical region close to the nearctic (montane) zone.

With the above described species, the Mexican species of *Aedes* (*Ochlerotatus*) now number 24 and of *Aedes* (*Gualteria*) 7.—Authors' summary.

PROBABLE INSECT VECTORS OF YELLOW FEVER VIRUS, FROM MONKEY TO MAN, IN BWAMBA COUNTY, UGANDA. Lumsden, W. H. R. Bull. Ent. Res. 42(2):317–330. 1951. The habits and habitations of the natives in the Bwamba lowlands, Uganda, are briefly described. A series of catches designed to assess the relative importance of the various species of biting insect and various routes of transference in the transmission of yellow fever virus from the monkey population of the forest to the nearby human population is reported. The microclimate in a native hut is discussed. The species of biting insects encountered are listed, the results of the catches given, and the relative importance of the different species and routes assessed by means of indices.

It is concluded that yellow fever virus is most likely to be transferred to the native population by *Aedes* (*S*) *simpsoni* in plantations, the infection in this insect being derived from forest monkeys which raid the plantations for food.—Author's summary.

STATUS OF MALARIA ON GREECE, CYPRUS AND SARDINIA. Prepared by Wm. J. Perry, LCDR (MSC) USN; Approved by M. E. Bell, Sci. Director. Tech. Rept. ONRL-63–51, Office of Naval Research, London. 6 pp. July 1951. The application of insecticidal sprays to villages under 2500 population to take advantage of the residual action of DDT and the utilization of larvicidal measures in those areas surrounding cities over 2500 people have greatly reduced the incidence of malaria in Greece.

The danger of a recurrent epidemic in hyperendemic areas such as exists on Sardinia, Cyprus and Greece is emphasized when natural immunity in indigenous populations is reduced by anopheline eradication campaigns. Adequate preventive measures should be continued.—Author's summary.

DISTRIBUTION AND CONTROL OF MOSQUITOES IN RICE FIELDS IN STANISLAUS COUNTY, CALIFORNIA. By Markos, B. G. Jour. Nat. Malaria Soc. 10(3): 233–247. 1951. Observations in rice fields in Stanislaus County, California, and adjoining areas, during the summer of 1947, revealed that

1. Rice fields are productive of large numbers of mosquitoes, which appear in three well-defined peaks. The *Aedes* mosquitoes, represented by *Aedes dorsalis* (Meigen), *Aedes nigromaculis* (Ludlow), and *Aedes vexans* (Meigen), appeared immediately after flooding, and then disappeared. In the early summer, *Culex tarsalis* Coquillett appeared, followed in the late summer by *Anopheles freeborni* Aitken.

2. *C. tarsalis* reached its peak during the last week of June and first week of July, *A. freeborni* reached its peak during August and September.

3. The centers of "checks" were found to be as productive of mosquito larvae as were the areas adjacent to the levees. Larvae of the

above-mentioned species were found to be well-distributed throughout the "check."

4. In view of the general distribution of mosquito larvae throughout the "checks," and because of the extensive areas involved, present control methods are virtually confined to the use of aerial sprays.

5. Aqueous emulsions of DDT and DDD, applied from an airplane at the rate of 0.3 pound per acre, gave excellent control for periods of one to two weeks.

6. The control of disease-bearing mosquitoes, such as those found in our studies, which breed in rice fields, is of prime public health importance, as they are known carriers of malaria and the encephalitides.—Author's summary.

The Housefly, by Luther S. West. Comstock Publishing Company, Inc., Ithaca, New York, 1951, 584 pp., 176 figures. Price $7.50. Entomologists, engineers, sanitarians, and medical men who are concerned with mosquito abatement projects are being drawn more and more into housefly control. Dr. West's book will make available to these workers much of the information, on all aspects of the housefly problem, that has been built up since the publication of the books by L. O. Howard (1911) and C. Gordon Hewitt (1914).

The author has done well in reviewing the voluminous literature on this world-wide pest and his own experience, especially in the Army, and has been drawn upon in several chapters. Control men will be particularly interested in the chapters on emergency and planned control, public health relations, and insecticides.

The morphology, physiology, life history, habits, ecological factors, natural enemies, and world distribution of flies of the genus *Musca* are discussed in considerable detail. Field, museum, and laboratory techniques are also given considerable attention.

The tabulation of species and subspecies and their distribution over-emphasizes the number of forms with which the entomologist and sanitarian have to deal. Although eight forms are listed as occurring in the New World, for all practical purposes, there is only one—*Musca domestica.* In a number of instances species are referred to the genus *Musca* which definitely belong in families other than Muscidae. Despite points of this kind and certain errors in the spelling of scientific names, we anticipate that this valuable book will be widely used as a reference work.—F. C. Bishopp.

Mosquito Abatement in California. Bureau of Vector Control Bull. No. VC-1. 47 pp. 19 illus. State of Calif. Dept. of Pub. Hlth. 1951. This bulletin briefly discusses the biology of the more important California mosquitoes and mentions some mosquito transmitted diseases. Summaries are given of the various principles and practices of mosquito control as drainage, filling, natural, and chemical control. Problems incidental to irrigation of forage and rice fields are also presented. Organization of the mosquito abatement districts is discussed as well as the part played in the mosquito problems of California by the State Department of Health, California Mosquito Control Association, and the Universities and Colleges. This bulletin would be extremely useful for providing background information to public officials concerned with the problem of financing mosquito control programs. —E. L. Seabrook, Palm Beach County Mosquito District, West Palm Beach, Florida.

(Ed. note: BVC address is 2180 Milvia St., Berkeley 4, Calif.)

Illustrated Map of the Anopheline Imagines of Indonesia. (English translation). Published by the Ministry of Health of Indonesia. 1949. 69 pp. Numerous Illustrations. This is a corrected and supplemented English edition of the excellent guide to the adult *Anopheles* of Indonesia published in 1938. The word "Map" in the title is misleading as the work contains no maps in the usual sense, but consists of brief statements by species of the principal characters in relation to malaria, and breeding places. Opposite these statements are excellent drawings of the more important taxonomic features, especially the mouthparts, wings, legs and male hypopygia. Sixty-two species and varieties of *Anopheles* and six of *Bironella* including four not found in Indonesia are included.

The large size of the book approximately 11x15 inches makes it difficult to file but has the advantage of permitting it to be opened flat and the characters to be seen at a glance on the large drawings and directly associated with descriptive material.

Apparently W. J. Stoker and R. Waktoedi Koesoemawinangoen are largely responsible for this publication which should be of much value to all those concerned with malaria control in Indonesia and especially to American workers who are assigned to projects in that region.—F. C. Bishopp.

A Series of Four Papers dealing with studies of the responses of the female *Aedes* mosquito appeared in the Bulletin of Entomological Research 42, Nos. 1 and 3. Data on this fundamental study was reported by A. W. A. Brown, D. S. Sarkaria, R. P. Thompson, and D. G. Peterson. Part I, entitled, "The Search for Attractant Vapours" described the authors' research with the attractiveness of water vapor, carbon dioxide, and candidate attractants. Moist air (85% R. H.) was found to attract 3 to 5 times as many female *Aedes aegypti* mosquitoes as dry air (15% R. H.). Pure CO_2 vapor proved to be no more attractive than dry air, and several times less attractive than moist air. However, the addition of 10% CO_2 to a dry air stream approximately doubles the number of mosquitoes attracted to an olfactometer. A number of chemical compounds found in body exudations were also tested in the olfactometer, but none were consistently attractive, and many were significantly

repellent. Sweat proved significantly attractive at a low vapor concentration but significantly repellent at a high concentration.

Part II was concerned with the action of liquid repellent compounds. The experiments reported in this section of the study assessed the repellent power of the vapors of a number of mosquito repellents by using olfactometer technique. It was concluded that vapor repellency was not simply a function of vapor pressure, but that it may also depend on the biological activity of the molecules in the vapor. Three compounds were found which afford not only a long protection period due to their nonvolatility, but also with a high vapor repellency due to the potency of the comparatively few molecules that are volatilised. Vapors of most of the repellents were found to induce knockdown of mosquitoes, but there was no correlation between the speed of this process and the vapor repellency.

The response of *Aedes aegypti* to a warm body and its radiation was discussed in Part III. The authors readily established the fact that warm bodies, 100° F., were more attractive than cool ones, 80° F., irrespective of their humidity. They then set out to distinguish the attractiveness between convective and radiant warmth. By using an air-tight window of thallium bromoiodide which allowed almost all of the radiation to filter through, the authors concluded that heat convection, which was not eliminated by the air-tight window, was the factor which makes a warm object attractive to the mosquito. In addition, surfaces which differed widely in their emission of radiant heat, but which had the same surface temperature, were found not to differ significantly from each other in attractiveness.

Part IV reported the results of data obtained by similar studies under field conditions. Several species of *Aedes* peculiar to the Canadian forest were involved. The investigations were made by means of a pair of robots so constructed, heated, and clothed as to constitute dummy men. Again the authors observed that moisture increased the attractiveness of a warm body 2 to 4 times when the air temperature exceeded 60° F., but that surface moisture decreased the attractiveness at cooler temperatures. Warmth increased the attractiveness, so that a robot at 98° F. attracted 3 times as many mosquitoes as one at 50 to 65° F. The authors, therefore, concluded that moisture was the major attractant factor when the air temperature exceeds 60° F., and warmth when the temperature was less than 60° F. Carbon dioxide vapor emitted from a robot's head almost doubled the attractiveness of a warm body. Vapors of ether and gasoline were significantly attractive. Robots clothed in sweat-soaked clothing were slightly but significantly more attractive than a water-soaked one. Light colors were less attractive than dark ones and luminescent dyes decreased the attractiveness of cloths. Green was less attractive than red or blue. Greenish-khaki nylon cloth was much less attractive than khaki drill or cotton. No interspecific differences in responses were observed. Part V dealing with the importance of visual responses in attractiveness, has been submitted for publication in the Bulletin of Entomological Research.—H. H. Stage.

A REPORT FROM THE GOOD NEIGHBOR CLUB was received from its chairman, Harry H. Stage, too late for inclusion in this issue of *Mosquito News*. There is space here to record only one or two items of special interest in that report.

Mrs. Ernestine Thurman, a member of this Committee now in Thailand, writes: "Thailand needs all available assistance from AMCA. Any effort on your part will not be wasted. The workers in malaria control are eager for information, literature, equipment, and encouragement. It was quite a blow to find a total void of natural history collections in the magnificent, spectacular national museum in Bangkok." Tommy Mulhern writes: "I have entered into the spirit of your Good Neighbor Club by paying up back dues of C. Y. Chow, our good friend who is in Formosa. You may not know it, but because of inflation, it costs Dr. Chow almost a week's salary for a stamp to write us. If someone else wants to participate in like fashion, they might take care of back dues of Teh-Nevg Chen, who is also in Formosa and whose account remains unpaid from 1948."

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